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Minerals and Metals in Ancient India

Volume II
Indigenous Literary Evidence

121597

Arun Kumar Biswas
Sulekha Biswas

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NEW DELHI-110015

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Cataloging in Publication Data — DK

Biswas, Arun Kumar, 1934 -
Minerals and Metals in Ancient India
Includes bibliographical references (p.).
Includes index.

1. Minerals -- India, Ancient. 2. Metals -- India, Ancient. 3. Metallurgy -- India, Ancient. 1. Biswas, Sulekha II. Title.

ISBN 81-246-0048-1 (set)
ISBN 81-246-0050-3 (vol. 2)

R
930.1028
Bis-M.2

First Published in India in 1996

© Prof. Arun Kumar Biswas, 1994

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Published and printed by :
D.K. Printworld (P) Ltd.
Regd. office : '*Sri Kunj*', F-52, Bali Nagar
New Delhi - 110015
Phone: (011) 546-6019; *Fax*: (011) 546-5926

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Preface

Minerals and Metals in Ancient India Volume I dealt with the archaeological evidences (foreigners' travel accounts also noted) showing the use of minerals and metals in ancient India, the period spanning from the Pre-Harappan era up to AD 1200.

This Volume II covers the period between the *Ṛgveda* and the early fourteenth century AD text *Rasaratnasamuccaya* dwelling on the indigenous literary evidences on the use of minerals and metals in ancient India, more particularly the relevant Sanskrit literature.

The archaeological evidences clearly prove that the ancient Indians were familiar with gems, non-gem minerals and metals, even before the Harappan era. The literary evidences however start with the *Ṛgveda* which, we believe, was contemporaneous with the Harappan civilization in the Sarasvatī Valley.

After an introduction to the subject in chapter 1, this dissertation begins with the Ṛgvedic evidences of the ancient metallurgy in India (chapter 2). The post-Ṛgvedic literature (chapter 3) mentioned specific metals including iron, a few gems and non-gem minerals. Surprisingly however, the details of iron-making or the newly invented potteries such as PGW/NBPW are not found even in the later Vedic literatures; this is probably an effect of the casteist division in the society.

Pāṇini's *Aṣṭādhyāyī* contains the etymological roots of many technical terms, evolved during the post-Vedic period, and refers to bellows, beryl and coins (chapter 4) which have been found during the archaeological excavations at Taxilā. *Kauṭilīya Arthaśāstra* describes the Mauryan political economy, the emergence of a large state, the increasing role of mines in the state economy, a large variety of gems constituting the elements of international trade and the diversity of alloys, coins and ornaments (chapter 5).

Chapter 6 in this volume examines the references to minerals and metals in the epic *Mahābhārata* which must have been compiled in the present form over several centuries.

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A millennium of the *Ratnaśāstra* texts is the subject-matter of chapter 7, in which the large variety of gems mentioned in the Sanskrit texts have been discussed from the modern scientific standpoint. Similarly, the *Rasaśāstra* texts dealing with chemical and metallic transformations, which evolved over centuries, have been comprehensively discussed in chapter 8.

Whereas *Rasaśāstra* or Indian alchemy indulged in an extravaganza of wild concepts such as conversion of base metals to gold, discovering a drug for immortality and so on, the subsequent literatures on iatrochemistry became more realistic. *Rasaratnasamuccaya* of the early fourteenth century AD period, is a pinnacle of Indian iatrochemistry and discussed in our penultimate chapter 9.

The last chapter summarises our findings; furthermore two specific topics are discussed therein. The problem of correlating the evidences in the Sanskrit literatures and the archaeological evidences has been critically examined. Secondly, we have made a brief presentation of the irrational as well as the rational or positive elements of philosophical thinking in India as revealed in the Sanskrit literatures related to minerals and metals.

Several appendices are presented at the end of this volume. The technical words appearing in the literature have been stratified: (A) modern scientific nomenclatures, then those belonging to, (B) *Ṛgveda* and post-Ṛgvedic period, (C) Pāṇini's *Aṣṭādhyāyī*, (D) *Kauṭilīya Arthaśāstra*, and (E) post-Christian eras. The entire Sanskrit literature on minerals and metals has been scanned from a modern standpoint, and therefore, appendix 'A' fittingly provides scientific information on the minerals discussed in this thesis. Our studies on the subject up to AD 1200 (earlier Volume I and this Volume II) are being extended to cover the pre-modern period (AD 1200-1900) as well.

Indian Institute of Technology
Kanpur, 1995

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Acknowledgement

WE are deeply indebted to the Indian National Commission for History of Science for sponsoring our work on Minerals and Metals in Ancient India up to AD 1200, extending financial assistance for the period 1987-91, and allowing us to publish the report in two volumes.

We heartily thank the Commission and the staff of the History of Science Division of the Indian National Science Academy, New Delhi for their splendid and manifold assistance.

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Abbreviations

Ait. Brā.	—	*Aitareya Brāhmaṇa*
AK	—	*Amarakośa*
AM	—	*Agastimata*
ARR	—	*Agastīya Ratnaparīkṣā*
AS	—	*Kauṭilīya Arthaśāstra*
ASHR	—	*Aṣṭāṅgahṛdaya*
Āsval. ŚS	—	*Āsvalāyaṇa Śrautrasūtra*
AV	—	*Atharva Veda*
BARC	—	Bhabha Atomic Research Centre, Bombay
B&RW	—	*Blue and Red Ware*
Bṛ.Saṁ.	—	*Bṛhat Saṁhitā*
B.Up.	—	*Bṛhadāraṇyaka Upaniṣad*
Chā. Up.	—	*Chāndogya Upaniṣad*
DKM	—	*Dhātukriyā* or *Dhātumañjarī*
DRN	—	*Dhāturatnamālā*
DV	—	*Dhātuvāda*
GP	—	*Garuḍa Purāṇa*
Jai. Brā.	—	*Jaiminīya Brāhmaṇa*
Jai. Brā. Up.	—	*Jaiminīya Brāhmaṇa Upaniṣad*
K. Y. V	—	*Kṛṣṇa Yajurveda*
Kā. ŚS	—	*Kātyāyana Śrauta Sūtra*
Kā. Saṃ.	—	*Kāṭhaka Saṃhitā*

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Kaṭha Up.	—	*Kaṭha Upaniṣad*
Kau. Brā.	—	*Kauṣītaki Brāhmaṇa*
Kau. S.	—	*Kauśika Sūtra*
LRP	—	*Laghu Ratna Parīkṣā*
Mait. Saṃ.	—	*Maitrāyaṇī Saṃhitā*
Mait.Up.	—	*Maitrāyaṇī Upaniṣad*
Manu	—	*Manu Smṛti*
MCK	—	E.J.H. Mackay's *Further Excavations at Mohenjo-daro* (Vol. 1)
ML	—	*Mānasollāsa*
MM	—	*Maṇimālā*
MS-I	—	J. Marshall's *Mohenjo-daro and the Indus Civilizations* (Vol. I)
MS-II	—	J. Marshall's *Mohenjo-daro and the Indus Civilizations* (Vol. II)
MSV	—	Madho Sarup Vats' *Excavation at Harappa* (Vol. 1)
NBPW	—	Northern Black Polished Ware
Nir.	—	*Nirukta*
NRP	—	*Navaratnaparīkṣā*
OCP	—	Ochre Coloured Pottery
Pam. Vi. Brā.	—	*Pañca Viṁsa Brāhmaṇa* or *Tāṇḍya Brāhmaṇa*
Pāṇ.	—	Pāṇini's *Aṣṭādhyāyī*
PGW	—	Painted Grey Ware
RASASA	—	*Rasendra-Sāra-Saṁgraha*
RCD	—	*Rasendracuḍāmaṇi*
RCM	—	*Rasacintāmaṇi*
RCT	—	*Rasendra-Cintāmaṇi*
RHR	—	*Rasahṛdaya*
RJL	—	*Rasajalalakṣmī*

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RKP	—	*Rasakalpa*
RN	—	*Rājanighanṭu*
RNM	—	*Rasanakṣatramālikā*
RNVK	—	*Rasārṇavakalpa*
RNV	—	*Rasārṇava*
RP	—	*Ratnaparīkṣā*
RPS	—	*Rasaprakāśa Sudhākara*
RR	—	*Rasa-Ratnākara*
RRS	—	*Rasaratnasamuccaya*
RS	—	*Ratnasaṁgraha*
ṚV	—	*Ṛgveda*
RYP	—	*Rayaṇaparikkhā*
RYT	—	*Rudrayamala Tantra*
Ś. Brā.	—	*Śatapatha Brāhmaṇa*
SP	—	*Skanda Purāṇa*
SSRS	—	*Sarveśvararasāyana*
ST	—	*Suvarṇatantra* or *Swarṇatantra*
Ś Y V	—	*Śukla Yajurveda*
S. Vi. Brā.	—	*Saḍa Viṁsa Brāhmaṇa*
Sāṅkh. Ā	—	*Sāṅkhyāyana Āraṇyaka*
Sāṅkh. ŚS	—	*Sāṅkhyāyana Śrautasūtra*
Tait. Ā	—	*Taittirīya Āraṇyaka*
Tait. Brā.	—	*Taittirīya Brāhmaṇa*
Tait. Saṃ.	—	*Taittirīya Samhitā* (Same as *K. YV*)
Vā. Saṃ.	—	*Vājasaneyi Samhitā*

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1

Introduction

THIS volume seeks to record ancient India's long acquaintance and sustained expertise in the fields of gems, non-gem minerals, metals and alloys, as revealed from the Vedic and Sanskrit literature. The period from the *Ṛgveda* to the *Rasaratnasamuccaya* (*RRS*) covers nearly three millennia. Traditionally, the 'ancient' period in India is said to have ended around AD 1200 with the firm grip of the Muslims over this sub-continent. Our narrative however includes *RRS*, an early fourteenth century AD treatise, since it provides a comprehensive review of the earlier Sanskrit literatures and the state-of-the art in the field of our interest. We have also given references to some Pāli and Prākṛt texts, to substantiate our findings.

A major problem about the literary sources, specially in terms of their correlation with the archaeological data, is concerned with their dates. The problem is specially acute with the *Rgveda*; we cannot accept Max Müller's proposition of 1200 BC as the date of the *Ṛgveda*, since this is the accepted date of the *Mahābhārata*-famed archaeological site of Hastināpura. The events of the Sarasvatī river valley, as described in the *Ṛgveda*, must have taken place in the third millennium BC, witnessing a fully grown Harappan civilization. This point shall be elaborated later. We also have controversies regarding the dates of Pāṇini, Kauṭilya, Nāgārjuna, etc., on which we would submit our considered opinions.

The writings on minerals and metals in the Sanskrit literature are surprisingly scanty and scattered. These have been often peripheral to other topics of interest such as philosophy, theology, poetry and history as in the Vedic literatures, and later grammar, political economy, prognostication, astrology, medicine and alchemy, etc. Fortunately, the writers and compilers of the above topics had some interest in gems, non-gem minerals, metals, alloys, etc. and thus we have

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been benefited from their treatises.

Another fact that stands out is that the references to minerals and metals appeared much after the actual uses had already been made. This was partly because, as we have explained, the writers were primarily interested in subjects other than minerals and metals. Another reason, probably the major one, behind this time-lag was the rigid division of labour and casteism which discouraged fast diffusion of knowledge. The metal-smiths were low-caste people, debarred from studying the *Vedas*, and the Vedic scholars were often ignorant of metallurgy. The traditional scholars took some interest in astronomy, mathematics and geometry on account of their involvement with the rituals, which were not concerned with smelting, pottery-making, etc. The gap between metallurgy and scholasticism however narrowed somewhat in the Maurya and Gupta eras.

We have tried to elucidate the ancient Sanskrit technical terms in the light of our modern scientific knowledge. In several cases, doubts and controversies persist. More research is necessary to fully explain certain terms such as *vaikṛntaka*, *capala*, *pulaka*, *bhīṣma*, etc.

Chapters 2 and 3 deal with the evidences from the *Ṛgveda* and other Vedic literatures, respectively. The writings of Pāṇini (chapter 4) and Kauṭilya (chapter 5) throw a flood of light on the ever-increasing use and knowledge of minerals and metals attending the second phase of urbanisation in the ancient India. The data on *Mahābhārata* (chapter 6) show how the epic was enlarged with metallurgical references inserted during the historical period after 500 BC.

One millennium of gemmology studies in India has been reviewed in chapter 7. The studies on medicine were initiated during the age of *Atharvaveda*, when botanical as well as mineralogical recipes were tried on patients, and their effects studied. From Caraka to Patañjali to Nāgārjuna, the *Rasaśāstra* was developed in stages which grew to its full stature during the Tāntric period of alchemy (AD 700 to 1300). Around AD 1300 started the iatrochemical period. Some fifteen centuries of progress in *Rasaśāstra* (reviewed in chapter 8) also reflected India's continuing involvement in gems, minerals and metals. Chapter 9 presents the highlights of the fourteenth century AD text *Rasaratnasamuccaya* which gives us almost the last word about 'ancient' India's progress in the field of our study.

The last chapter contains our concluding remarks, and highlights the following points pertaining to the Sanskrit literatures on minerals and metals in ancient India :

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(a) Correlation of the literary evidences with the archaeological data and other historical facts, and

(b) The revelations about the scientific concepts and socio-philosophical attitude in ancient India.

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2

Minerals and Metals in the *Ṛgveda*

THE *Rgveda* (*ṚV*) is the oldest Indo-Āryan literary document available to us. Before we discuss the metals and minerals mentioned in the *Ṛgveda*, we may briefly comment on the controversial views on its authorship and date of compilation.

Max Müller, the famous scholar and translator of the *Ṛgveda*, noticed the similarities between the Indo-European languages and proposed in 1859, that *Ṛgveda* was compiled around 1200 BC by the Āryans 'who had come to India from outside around 1500 BC' (Max Müller, 1859) His theory was shown by Winternitz, Bühler, Macdonnel, Muir, etc. to be based on very flimsy premises. John Muir asserted in 1872 that the Ṛgvedic Āryans were not aware of any land outside India, and also that 'the nations whose speech is derived from Sanskrit have sprung from the gradual dispersal of the ancient Āryan race of India'. (Muir, 1872:2, 322-23). The most recent rebuttal of Max Müller's dates has been recorded by K.C. Varma (1987). We agree with Winternitz that 'no power on earth can anytime be sure whether the Vedic hymns were composed 1000 or 2000 or 3000 years before Christ'. As a matter of fact, the verses were orally transmitted through centuries, and the only question is: in which era in the pre-history did the events, narrated in the verses, actually take place.

Our considered opinion is that the *Ṛgveda* corresponds to the ancient civilization on the valley of the lost river (*vinaśana*) Sarasvatī. (Biswas, 1987) The archaeological expeditions have unearthed not only the ancient course of the said river (Stein, 1942; Ghose *et al.*, 1979) but also the details of many important sites on the river such as Kālibaṅgan (Lal, 1979), Banawālī (Bisht, 1982), Bhagwānpurā (Lal, 1982), etc. C-14 measurements have shown that the different strata of the above settlements ranged from 3000 to 1500 BC. In other words, the Ṛgvedic culture was Pre-, Mature- as well as Post-Harappan. We

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agree with B.B. Lal (1982:337) that the uninterrupted sequence from the Pre-Harappan ploughed field to the Post-Harappan PGW 'formed the base on which the Mature Harappan appeared like bubbles on a vast lake, only to disappear and merge into the waters of the lake itself'.

In other words, we consider that the myth of 'foreigner Āryans invading India and destroying the totally different Harappan culture' is fictitious, unproven and unacceptable. Many scholars have provided arguments as to why the myth cannot be accepted at the present level of our knowledge. (Dales, 1964; Poliakov, 1974; Shaffer, 1984; Srivastava, 1984; Biswas, 1988)

It appears more likely that the Ṛgvedic civilization was indigenous and, flourishing on the banks of the Sarasvatī and its tributaries such as Dṛṣadvatī, Śatadru or Sutlej, was neolithic or mesolithic in the Pre-Harappan, and chalcolithic during the Mature-Harappan era. Its economy was essentially agro-rural when it came into contact with the economically exploiting class of the Panis or Harappan traders. The Ṛgvedic war was basically a civil war fought around 2500-2000 BC and won by the authors of the *Ṛgveda*. Their opponents belonged to the same racial stock but different religious sect. As the Sarasvatī river got dried up, the Ṛgvedic people moved towards the eastern valley of Gaṅgā and Yamunā and continued with the later part of the Vedic civilization, lasting up to 800 BC and heralding the onset of the second urbanisation and the Historical Period in India.

Transition from the Neolithic to the Chalcolithic Age

Ṛgveda is not a manual on metallurgy, and hence we cannot expect too many details on minerals and metals in this earliest literature of mankind. Yet we do obtain here a glimpse into the transition from the neolithic to the chalcolithic age in India.

Ṛgveda (*ṚV*) contains several words for the stone: *aśman*, *adri*, *pāṣya*, etc., of which the first, i.e., *aśman* is the most significant one. Mehta and Kantawala (1987) have discussed the varieties of stone-tools in the *Ṛgveda*. In *ṚV*, 1.191.15 the text *bhinadmy aśmanā* indicated a cutting stone-tool which could be a blade, celt or cleaver. The *aśmānam vajram* (*RV*, 4.22.1) is evidently a *vajra* or weapon made of stone. Later a similar weapon was made of *ayasa* or metal. The simultaneous appearance of the words *kārmāra* and *aśman* in 9.112.2 led Mehta *et al.* (1987) to propose that *kārmāra* was a stone-worker rather than a blacksmith. It may be recorded here that in the Pre-Harappan stratum of Kālibaṅgan, chalcedony and agate blades have been found. These were serrated, mounted on wooden handle and probably used for cutting and sowing. At a later

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stage, chert blades were introduced. Side by side copper-made axe and *paraśu* were found, the latter probably used for cutting scrubby bushes. (Lal, 1979:70) Chert and chalcedony blades have been found at Banawālī also. (Bisht, 1982)

The *vāśī* in the *Ṛgveda* is probably an adze with a flat surface and a sloping edge for cutting or rough shaping of wooden materials. Its modern equivalent could be the carpenter's *basulā* (Hindi). Mehta *et al.* (1987) have pointed out that whereas *ṚV,* 10.101.10 refers to *aśmanmayī vāśī* or stone-made implement, *ṚV,* 8.29.3 mentions *vāśīm āyasīm* or a metallic axe. Sāyaṇa explains that this could be a stone adze with a metallic edge.

Fire in Matallurgy

It is evident that the transition from the neolithic to the chalcolithic age has been subtly depicted in the *Ṛgveda*. This transition was possible only through the discovery and use of fire. Generation of fire by friction (3.29.1), and its sustenance by the fire-wood (*araṇī)* and the fuel-wood (*atas*) have been described in the *Ṛgveda* (vide Appendix B — reference to *agni*, *atas* and *araṇī*).

Agni or fire has been described as the cradle of (metallic) gems: *ratnadhātamam* (1.1.1). Here quite evidently, *ratna* or gem stands for metallic gems like gold and silver. These two metals and also copper have been known to exist in the native or metallic state. It is quite likely that man obtained these three metals in the chalcolithic age solely by melting the ore, using fire and some kind of furnace. At a later stage, copper ores (sulphide or oxide) were smelted or reduced to the metallic state by using fuel-wood or *atas*, the carbonaceous matter in it serving as the fuel as well as the reductant.

The valuable ore body has been known in the Vedic literature as *nidhi* (*ṚV,* 2.24.6 etc.). Mining was known in elementary form. The mined product *khanitrima* (7.49.2) was obtained by using digging tool or *khanitra* (1.179.6). Grinding (1.28.4), using *muṣala* or pestle and *ulukhala* or mortar (1.28.1-6) was done before the ore-body was put into the furnace.

We have indicated before the controversy as to whether *kārmāra* in 9.112.2 stands for stone-worker or blacksmith. May be there was no fine distinction between the two professions in the Ṛgvedic age. *Kārmāra* in *ṚV*, 10.72.2 was however clearly a metalsmith who blew in a furnace and made metal objects presumably by casting of molten metal. He is associated with the act of blowing (*dhama*) in a furnace in order to purify or prepare the metal (*ṚV,* 4.2.17, 10.72.2), and was therefore known as *dhmātarī* or one who blows (5.9.5).

ध्मातेव धमति शिशीते ध्मातरी यथा

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dhmāteva dhamati śiśīte dhmātarī yathā
(5.9.5)

ब्रह्मणस्पतिरेता सं कर्मार इवाधमत्
brahmaṇaspatiretā saṃ karmāra ivādhamat
(10.72.2)

The metallic gem thus obtained by the smelting or melting process was known as *draviṇa* (4.5.11, 4.23.4 etc.) and the smelter was known as the melter or *dravi* (6.3.4) also.

The Meaning of *Ayas*

The *sūkta* 9.112.2 has been referred to earlier. The full text reads:

जरतीभिः ओषधीभिः पर्णेभिः शकुनानाम्
कार्मारो अश्मभिः द्युभिः हिरण्यवन्तम् इच्छति
jaratībhiḥ oṣadhībhiḥ parṇebhiḥ śakunānām
kārmāro aśmabhiḥ dyubhiḥ hiraṇyavantam icchati
(9.112.2)

Mehta *et al*. (1987) felt that *kārmāra* here could mean a stone-worker. Banerji (1929) however accepted Schraeder's earlier suggestion that the hymn actually described a smithy. Banerji argued that the passage alludes to the making of carburised iron. The Ṛgvedic smith, according to Banerji, used to convert the bright quartzian magnetic stone of iron oxide to iron through reduction by the carbonaceous dried medicinal plant, and then to carburise it by fusing with birds' wings,

Indirectly, Banerji proposes that the word *ayas* in the *Ṛgveda* means iron. We do not subscribe to his views. Iron was not discovered in the age of the *Ṛgveda*. The Sarasvatī valley archaeological sites have not yielded any iron specimen. Iron appeared in India much later, around 1200 BC.

The word *ayas* in the *Ṛgveda* (1.57.3, 1.163.9, 4.2.17, 6.3.5, 10.53.9-10 etc.) means metal in general, and not iron in particular. In the Ṛgvedic age it probably corresponded to copper and its alloys. In the subsequent Vedic literature, copper was mentioned as the red metal and iron as the black metal. This also proves that *ayas* in the *Ṛgveda* could not mean iron specifically. We would propose that the hymn 9.112.2 might have alluded to the making of copper metal through the reduction of its ore or simply to the melting of gold-bearing quartz. The end product of golden ornament, copper implement or copper-tipped arrow were sold to the moneyed people by the metalsmiths.

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The words *āyasī* and *ayasmaya* meant metallic commodity, and fire was characterised as *ayodanṣṭra* (1.88.5, 10.87.2), that which bites metal.

Some Metallic Objects

For agriculture, the Ṛgvedic people used plough which had various names e.g., *phāla* (4.57.8, 10.117.7), *lāṅgala* (4.57.4), *vṛka* (1.117.21, 8.22.6), *sīrā* (4.57.5 & 8, 10.101.3-4). Sītā (the name of the heroine in *Rāmāyaṇa*) means the line or furrow tilled by the plough. The tip of the plough known as *phāla* or *śunā* (4.57.5 & 8) might have been made of sharpened stone during the neolithic age, but was metallic in the chalcolithic era. Sickles *dātra* (8.78.10) and *sṛṇī* (10.101.3) — were used for cutting the crops.

Next to the ploughshare, the most important metallic tool in the hands of the Ṛgvedic people were the axe the chisel or the adze which were used to cut the forest trees and utilised as the carpenter's tool. We have earlier discussed that chisels or adzes, *vāśī* or *basulā* were stone-made in the neolithic age (10.101.10) and became metallic in the chalcolithic age (8.29.3). *Kṛti* was a chopper or cutter (1.92.10, 1.168.3), more like a sword, and eventually developed as a scissor. *Swadhiti* (2.39.7, 3.8.11) was a similar instrument. The name sounds similar to sword. *Bhurija* (4.2.14, 8.4.16, 9.71.5) was a carpenter's tool used in the making of chariots.

Kuliśa (1.32.5) was the axe, the modern *kulhaḍe* or *kuṭhāra*. *Paraśu*, also a sharpened metallic axe, was an offensive weapon. The cow-plunderers 'came to the east with big *paraśu*' to attack the Ṛgvedic people (7.83.1). *Vadhara* and *heti* were also weapons, the details of which are not known.

Several names were used to indicate an arrow: *iṣu*, *bāṇa*, *bunda*, *śaru*, *śarya*, *śaryā*,*saru* and *sāyaka*. Copper-tipped arrows were evidently not enough to kill the enemy, and therefore poisonous materials were used on the tips: *ālāktā ayomukham iṣu* (6.75.15). There were several kinds of javelins or spears to be thrown at the enemies: *sṛka* (*sṛja* means to let go or fly), *pavi* (10.180.2), *ṛṣṭī* (1.37.1, 1.64.4, 8.20.11 etc.). The action is clearly conveyed in the text *ṛṣṭīḥ asṛkṣata* (5.52.6). *Vajra* (1.32.2, 1.51.7, 6.23.4) was probably a spear or a barbed harpoon. The metal spike (*śūla*, 1.162.11) and the knife (*sūna*, 1.162.13) could be used either for offensive combats or in connection with cooking.

Closer to the domestic scene, we find the uses of the razor (*kṣura*, 1.166.10, 10.142.4), needle (*vesī*, 7.18.17 and *sūcī*, 2.32.4), (some metallic) pitchers (*āhāva*, *kalaśa* and *kuṁbha*) and some musical instruments such as *āghāti* (10.146.2) or cymbal and *karkari* (2.43.3) or lute.

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Some of the copper implements actually found in the Sarasvatī Valley sites are:

Kālibaṅgan — celt, hammer, bangle, arrow, fish-hook, axe, *paraśu*, mirror, pin. (Lal, 1979)

Banawālī — arrowhead, bangle, spearhead, sickle blade, razor, chisel, ring, double spiralled and simple pin, ear/nose ring/fish-hook. (Bisht, 1982)

The Sarasvatī Valley copper artefacts were not alloyed with tin, and therefore not as hard as those from Harappa and Mohenjo-Daro.

Ornaments and Gems

In the *Ṛgveda*, silver has been mentioned only once (*rajata*, 8.25.22). The Sarasvatī Valley has been far from the sources of silver. The Indus system of rivers however provided bank sands containing alluvial gold particles. These rivers were called *hiraṇyavartanī* (6.61.7, 8.26.18, 10.75.8), the golden ways.

Quite naturally, the *Ṛgveda* contains references to many golden objects such as a pitcher made of gold (1.117.12). *Khādi* was the general term for golden ornaments: bracelet, armlet or bangle *hasteṣu khādi* (1.168.3) *khādi hastaṃ* (5.58.2), anklet, *patsu khādayo* (5.54.11), shoulder decoration, *aṁseṣu khādayo* (7.56.13) etc. On the finger, *khādi* was known as *vṛṣakhādi* or ring (1.64.10). Armlet or *kavaca* was also known as *pratyatkān* (5.55.6). The golden crown or *tiara* was known as *śiprā*; this was worn on the forehead:

शिप्राः शीर्षसु वितता हिरण्ययीः
śiprāḥ śīrṣasu vitatā hiraṇyayīḥ
(5.54.11, 8.7.25)

Rukmā was defined as the chest ornament made of gold : *vakṣaḥsu rukmā* (5.54.11).

Gold ornamental pieces to decorate neck were known as *niṣka* (2.33.10). *Niṣkagrība* meant golden necklace (5.19.3). There was no minted money or golden coin during the Ṛgvedic era, but possibly *niṣka*, as a golden lump, often served as the barter or exchange unit of money (1.126.2, 4.37.4, 5.27.2).

Añji (5.53.4) and *swadhā* (4.10.6) were certain kinds of ornaments, the details of which are not known. *Karṇaśovana* (8.78.3) was evidently the golden ornament for the ear. Excavations at Banawālī have yielded gold necklaces, gold beads and gold-plated terracotta beads. (Bisht, 1982)

The *Ṛgveda* refers to gems or *ratna* several times starting from its very first

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hymn (1.1.1). The other name of gem was *maṇi*, that which decorates (*maṇḍana*). Gems other than metallic gems were specially recognised.

हिरण्येन मणिना श्रुम्भमाना:
hiraṇyena maṇinā śrumbhamānāḥ
(1.33.8)

हिरण्यकर्णं मणिग्रीवम्
hiraṇyakarṇaṃ maṇigrīvam
(1.122.14)

The latter reference alludes to golden ear-ring and a necklace made of gems the like of which has been found at Banawālī. (Bisht, 1982) The *Ṛgveda* does not discuss different kinds of gems but at least one, namely pearl or *kṛśana* has been specifially mentioned: *abhivṛtaṃ kṛśanai* (1.35.4).

Archaeological excavations at Kālibaṅgan have yielded bangles of copper, shell and terracotta, beads of shell, copper, agate and carnelian copper mirrors, ivory combs, etc. At Banawālī we find in the Pre-Harappan level beads of gold, semi-precious stones, steatite (including disc beads), faience, shell, bone and clay; bangles of shell, faience and copper. At the Mature-Harappan level, a jewellery dealer's large house has been excavated. This was found to contain beads of etched carnelian, gold and *lapis lazuli*. Also found were gold-plated terracotta beads and numerous steatite seals. At Banawālī, beautiful golden ornaments and finely cut smoky brown crystal stones showed the heights of fine gem craftsmanship. Evidently this river-port was an important and prosperous trading centre. During the Post-Harappan period, the cultural pattern changed at Banawālī. The Harappan seal, chert weights, steatite disc beads, etc. disappeared. The Indus economy had collapsed. But the qualitative and quantitative profusion of faience ornaments such as bangles, anklets, rings, beads and *pīpal*-leaf-shaped ear-rings continued to meet the local requirements. The faience items had noteworthy and shiny silvery coatings.

Conclusion

There is thus reasonable correlation between the Sarasvatī Valley archaeological data, that we have gathered in India after Independence, and the information in the *Ṛgveda*. The Pre-Harappan Sothi culture that had evolved in the Sarasvatī Valley was influenced by the later day Harappan, and yet the original setting of the Ṛgvedic culture was retained even after the demise of the Harappan civilization. The clay stele *Śivaliṅgas*, the fire-worship, the animal sacrifice as religious ritual, and the segregation of population (along caste lines?) at Kālibaṅgan clearly show the Ṛgvedic culture. Mother Goddess and ram

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figurines at Banawālī and Bhagwānpurā indicate the Sarasvatī cult. The *paṇis* or the merchants at Banawālī became parts of the Ṛgvedic culture representing islands of affluence in an ocean of agro-rural setting. Gamesman type of ivory or bone cubes remind one of the Ṛgvedic poetry related to a dice player (10.34.1-14). The merchants used to bring *lapis lazuli* from Afghanistan or Persia, etched carnelian beads from Gujarat and Copper celts from Gaṇeśwar-Jodhpura in Rajasthan.

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3

Minerals and Metals in the Vedic Literature after *Ṛgveda*

BEFORE pursuing our observations on the Vedic literature we wish to re-emphasize why a separate discussion on the *Rgveda* was undertaken in the previous chapter. The reason was that we had to be firm about the authorship and date of the *Ṛgveda*. The idea that the so-called Āryans came from outside, entered India around 1500 BC and composed the *Rgveda* around 1200 BC has to be abandoned once for all. This is the considered view of most of the modern scholars whom we have quoted in the previous chapter. (Dyson, 1982; Shaffer, 1984)

Jim Shaffer has been most categorical:

> Current archaeological data do not support the existence of an Indo-Āryan or European invasion into South Asia at any time in pre- or proto-historic periods.

Thus we were fully entitled to submit that the Ṛgvedic civilization thrived at Kālibaṅgan, Banawālī, Bhagwānpurā, etc. on the Sarasvatī Valley **indigenously**, during the third millennium BC.

During the beginning of the second millennium BC, there were neo-tectonic movements in the northern part of India (Rajaguru, 1977: 69-72) causing diversion of the earlier channels of Sutlej and Yamunā away from the Sarasvatī. (Raikes, 1968; Pal, Sahai *et al.*, 1980) This caused gradual drying up of the Sarasvatī. The Sanskrit literatures mentioned some of these events in the form of legends: shifting of the course of Yamunā towards Brndābana (*Visnupurānam*, 5.18 and 5.26.11), submergence of the old city of Hastināpura (*Śrīmadbhāgavatam*, 10.68.41-42), desertion of the Sarasvatī river valley and

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migration of the Ṛgvedic people towards the east for *sadānīra* or the perennial rivers.

The vast Vedic literature following the *Ṛgveda* was compiled between 2000 to 800 BC in the valleys of the Gaṅgā and Yamunā. The *Brāhmaṇas* explain the verses in the *Vedas* and codify the rituals. The later day *Sūtras* describe the rituals in a serial order. Quite naturally, the studies on the material universe were picked up from the point the *Ṛgveda* left them.

In *ṚV*, 10.129.1-7, the Vedic bard wonders how this universe originated. Muir translates the statement in the fifth hymn *svadhāḥ adhastāt prayatiḥ parastāt* (10.129.5) as 'a self-supporting principle beneath, and (spiritual) energy aloft'. Our concern here is not with the spiritual energy of the Creator but with 'self-supporting principle' in this world of creation. *B.Up.* describes the cosmic evolution: 'Initially the universe was only space. Gradually it condensed to form atmosphere and then water. The earth differentiated in the form of dense layer on the primordial water:

यदपां शर आसीत् तत् समहन्यत। सा पृथिवी अभवत्
yadapāṃ śara āsīt tat samahanyata । sā pṛthivī abhavat
(*B.Up.*, 1.2. 1-3)

The *Ś. Brā* continues the theory of material evolution: 'From water was created foam, from foam to clay; clay gave rise to sand, then subsequent steps evolved pebble, stone, metal ore, and gold'. (*Ś. Brā,* 6.1.3.1-5) The *Kaṭha Upaniṣad* conceived of the smallest state of existence of matter, namely an *aṇu* or a molecule, and proposed that consciousness or the self is greater than the greatest and yet subtler than the smallest:

अणोरणीयान् महतो महीयान्
aṇoraṇīyān mahato mahīyān
(*Kaṭha Up.*, 1.2.20)

Minerals and Metals

The word *nidhi* representing mineral treasures was mentioned in *ṚV,* 2.24.6, 8.29.6, 10.68.6 etc., and repeated later as in *AV,* 10.7.23. Commenting on the passage 7.1.2 in the *Chāndogya Upanisad,* wherein several branches of knowledge such as *rāśī* or mathematics, *bhūtavidyā* or physics and *nidhi* or mineralogy were mentioned, the great commentator Śaṅkarācārya referred to '*nidhim*, the subject of mineralogy as found in books, like, *Mahakala*, etc.'. We do not know the author or the approximate date of compilation of this book.

The use of a winnow must have been very ancient, this having been depicted

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in a Harappan seal. The *Atharva Veda* was the first literature in which this is mentioned as a *śūrpa*. The hymns 9.6.15-16 (and also 11.2.1 and 11.8.3-4) describe the roles of the mortar and pestle in corn pounding, followed by the use of a *śūrpa* or a winnow in separating the grain from the husk. Now we know that the principle of separation is based on the non-terminal pneumatic settling of particles. This technique as well as the hydraulic (in water) gravity-settling process must have been used to separate the fine/coarse and light/heavy mineral particles. This separation process was recognised as a step of purification: *śūrpaṃ pavitraṃ tuṣā* (*AV*, 9.6.16) for which air served as the medium of separation: *śūrpagrāhī vātoipāvinak* (*AV*, 11.8.4).

The words related to purification: *pavana*, *pavamāna*, *pavitra*, etc. appeared in many places and under different contexts. We have already discussed pneumatic separation as in winnowing; purifying the juice of *soma* through a strainer or filter represented another kind (*ṚV*, 1.28.9, 3.36.7, *AV*, 6.124.3, 9.6.16, 12.3.3, etc.), for which the word *pavitra* was used. Purification by roasting or smelting was well recognised, and *agni* or fire was qualified as *pavamāna* or that which purifies (*Ait. Brā*, 2.37, *Tait. Brā.* 1.1.5.10, 2.2.4.2., *Ś. Brā*, 2.2.1.6, 2.2.3.22, etc.).

The word for charcoal namely *aṅgāra* appears in the *B.Up.*, 3.9.18 in connection with the instrument tong or *aṅgāra-abakṣayanam* which was used to handle hot pieces of charcoal in a furnace. The word *bhastrā* meant leather-bag in *Ś.Brā* (1.1.2.7, 1.6.3.16), and eventually it also meant the leather bellow used to blow air into a furnace. *Dhmātri* meant bellow, blow pipe, and the smelter—*prathamā vibhakti dhmātā* in *ṚV*, 5.9.5. *Dhmātri* has also been used in *saptamī vibhakti* meaning 'in the furnace of smelting'. The act of smelting or melting is mentioned in the Vedic literature (*ṚV*, 4.2.17, *Ś.Brā*, 6.1.3.5).

Different Kinds of *Ayas*

We have explained in the previous chapter that in the *Ṛgveda*, *ayas* meant metal in general and not iron specifically. As a matter of fact, iron was discovered in India much later; the *Ṛgveda* mentioned gold and silver specifically, and *ayas* mentioned therein probably corresponded to copper and bronze.

Śukla Yajurveda (*Ś.YV*) or *Vājasaneyi Saṃhitā* (*Vā. Saṃ*) was probably the first Indian literature to mention *śyāma* or iron specifically, along with a few other metals: *hiraṇya* (gold), *mehaja* (silver), *loha* (copper), *sīsā* (lead) and *trapu* (tin) (*Ś.YV*, 18.13). In the *Atharva Veda* (*AV*), a cosmic supernatural being has been described to have different part of the body resembling different metals including *śyāma* :

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श्याममयः अस्य मांसानि लोहितमस्य लोहितम्
त्रपु भस्म हरितं वर्णः पुष्करमस्य गन्धः
śyāmamayaḥ asya māṃsāni lohitamasya lohitam
trapu bhasma haritaṃ varṇaḥ puṣkaramasya gandhaḥ
(*AV*,11.8.7-8)

Do the above references indicate that these portions of the text in *Ś.YV* and *AV* were collated after twelfth century BC, the earliest date for archaeological specimen of iron (*śyāma*) in India? We are sure that *loha* (copper), *sīsā* (lead) and *trapu* (tin) were known and used in India much earlier, even though these names do not appear in the *Ṛgveda*.

Śyāma appears in many other literatures such as *AV*, 9.5.4, *Ś. Brā*, 13.2.2.16, *Kā. Saṃ* 18.10, *Mait. Saṃ.* 2.11.5 etc. At a later stage, iron was also known as *kṛṣṇāyas* or *kārṣṇāyas* or black metal (*Jai. Brā. Up.*, 3.17.3). A very clear reference is obtained in the *Chāndogya Upaniṣad*:

नखकृन्तनेन सर्वकार्ष्णायसं विज्ञातम् . . . . .
. . . . . कृष्णायसं इति एव सत्यं
nakhakṛntanena sarvakārṣṇāyasaṃ vijñātam . . . . .
. . . . . kṛṣṇāyasaṃ iti eva satyaṃ
(*Chā. Up.*,6.1.6)

By knowing a nailcutter all things made of iron become known
. . . . . Iron as such is the reality.

The previous passage in *Chā. Up.* (6.1.5) mentions that by knowing a copper bead or *lohamaṇi* all things made of copper or *loha* (red metal) are known. Another interesting passage in *Chā.Up.* (4.17.7) provides interesting lessons in metallurgy: 'One would join gold with the help of borax (*lavaṇa*), silver with the help of gold, tin (*trapu*) with the help of silver, lead (*sīsā*) with the help of tin, copper (*loha*) with the help of lead and timber with copper or leather'. Here the word *loha* has been misconstrued as iron by several scholars. *Loha*, *lohāyas* or *lohitāyas* is clearly copper, the red metal (*Ś.Brā.*, 5.4.1.1, and 2, 13.2.2.18; *Mait. Saṃ*, 2.11.5, 4.4.4; *Kā. Saṃ*, 18.10).

On *Trapu* or Tin

We have already referred to the early citations on *trapu Ś.YV*, 18.13, *AV*, 11.8.7-8, *Chā.Up*, 4.17.7). Several other words for tin, such as *kastira*, *vaṅga* and *raṅga* were evolved during the much later Historical period in India.

The word *trapu* is derived from the root *trap*, which means 'to be ashamed or

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shy', to which the suffix *un* has been added to convey the sense *agniṃ dṛṣṭavā trapate lajjate iva* (Tārānātha's *Vācaspatyam* quoted by V.S. Apte, 1890, 1985: 483; also Monier-Williams, 1899, 1986: 457) or that the low melting point metal easily melts in fire. It may be noted than tin has a very low melting point 232°C and low latent heat of melting 14.5 cal/gm.

Monier-Williams (1899, 1986: 266) suggested that the word *kastira* was derived from the root *kāns* or to shine, and led to the Greek word *kassiteros* for tin and the modern word cassiterite, for tin ore. Many scholars on the other hand (such as Chakrabarti, 1979: 68-69) believe that *kastira* was derived from the Greek word *kassiteros*. We subscribe to the latter view on account of two reasons. Firstly, the word *kastira* was used in the Indian literature during the period of Indo-Greek contact few centuries before the Christian era, not earlier and rarely later. Secondly, whereas the Indian word for brass has been traditionally *pīta tāla* or *pītala*, the other word which was used during the period of Indo-Greek contact, namely *ārakūta* (Kauṭilya's *Arthaśāstra*) seemed to be a loan word from the Greek *Oreichalcos*.

Monier-Williams's suggestion regarding *kāns* (to shine or to glitter) as the root for *kastira* cannot be altogether ignored specially in view of the strong possibility that this root might have led to the famous word *kaṅsā* which stands for the copper-tin alloy bronze, also known as bell-metal or white copper. The word *kaṅsā* has been generally used to indicate copper alloys, not necessarily containing tin. Just as *trapu* has sometimes denoted (erroneously) lead, similarly *kaṅsā* has often stood for brass (copper-zinc alloy) or copper-arsenic alloy. The Sanskrit name for arsenic mineral löllingite is *kāṅsya vimala*.

Kaṅsā or bronze has been used widely in the Harappan and Vedic civilization for making various utensils (*Ait. Brā*, 8.10, *Nir*. 7.23) such as vessels or bowls (*B.Up*., 6.3.1). Small pieces of *kaṅsā* were used as exchange units (*śataṃ kaṅsāḥ, AV*, 10.10.5).

On Lead

On account of its low melting point (327°C and low latent heat of fusion (6 cal/gm), lead has sometimes been confused with tin. This is attested by its misleading equations with *trapu*. As we have quoted earlier (*Ś.YV* or *Vā. Saṁ*, 18.13, *Chā. Up*., 4.17.7) tin (*trapu*) and lead (*sīsā*) have been mentioned as different metals. Monier-Williams and other scholars have failed to discover the etymological origin of *sīsā* or *sīsaka* signifying lead. There are many other references to the use of this metal (*Tait. Brā*., 2.6.42, 3.12.6.5; *Mait.Saṃ*., 2.4.2; 3.11.9; *Ś. Brā*., 5.1.2.14; 5.4.1.9; 12.7.1.7, etc.). In *Ś. Brā*., 5.4.1.10, the softness

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of lead metal has been emphasized. *Ś. YV* or *Vā. Saṃ.*, 19.80 mentioned the use of heavy pieces of lead in the art of weaving: *sīsena tantraṃ . . . ūrṇāsūtreṇa*. Like other metal pieces, lead has also been used as a medium of barter (*Ś.Brā.*, 12.7.2.10-12). In the *Atharva Veda*, lead powder was reported to have medicinal value in curing tuberculosis of human beings and cows (*AV*, 12.2.1), when used in small doses. That it acts as a poison when administered in larger doses was also understood (*AV*, 1.16.2 and 4).

Ornamental and Barter Metals

Silver and gold were the principal metals in the Vedic era for producing ornaments and the uses as the medium of financial transactions. In the previous chapter we have provided numerous examples of the use of *hiraṇya* or gold in the age of the *Ṛgveda*. This yellow metal was known as *harita* in the *Atharva Veda* (*AV*, 5.28.1, 5 and 9), *hariśiprā* in *ṚV*, 10.96.4, probably means yellow (golden) *tiara*.

We have mentioned different kinds of golden ornaments used in the Ṛgvedic era. We need not repeat those names; the items continued to be used in the post-Ṛgvedic period. In *Ś. Brā.*, 5.4.1.12-13 *rukmā* or gold plate is mentioned to contain sometimes a hundered holes (*śatavitṛnna*), sometimes nine holes (*navavitṛnna)*. Sacrificers often gave as a *dakṣinā,* a golden plate with eight indentations (*Āpastamba Sūtra*, 9,18, 16-19, 14). Other forms of gold offering were: gold chips or shavings, *hiraṇya sakala* (*Ś.Brā.*, 6.1.2.30, 7.5.2.8-9), *hiraṇya iṣṭaka* or gold-brick (*Ś. Brā.*, 6.1.2.30). The *Ś. Brā.*, 12.8.3.11 mentions gold and silver plates placed beneath the feet of the sacrificer at the consecration during the *Sautrāmaṇi* sacrifice. The *Āsval. ŚS* (10.3) and *Sāṅkh. ŚS* (15.27) state that a *hotṛ* priest should sit on a golden cushion (*hiraṇyakaśipu*), cushion in which gold threads are woven, during the *Rājasūya* sacrifice.

AV, 19.26.1-3 mentioned the bright metal gold 'born out of fire':

> अग्नेः प्रजातं हिरण्यम् अमृतम् . . . सूर्येण
> सुवर्णं . . . हिरण्यतेजसा विभासासि
> *agneḥ prajātaṃ hiraṇyam amṛtam . . . sūryeṇa*
> *suvarṇam . . . . hiraṇyatejasā vibhāsāsi . . . .*

Gold was obtained after melting the impure metal taken out from the mines (*Ś. Brā.*, 6.1.3.5, *Pam. Vi. Brā.*, 17.6.4). There is mention of *nis + tap* heating and melting in *Jai. Brā.*, 1.10 and *Jai. Brā. Up.*, 3.34.6. Golden ornaments, mentioned in the previous chapter, were also modelled in silver.

Silver or *rajata* was scarcely mentioned in the *Ṛgveda*; probably it was not

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easily available around the Sarasvatī Valley. Eventually we find many references of silver, occasionally substituting gold in *ruksma* and *niṣka*. Silver was used in making ornaments like *rukma* (*Ś. Brā.*, 12.8.3.11), preparing vessels or *pātra* (*Tait. Brā.*, 2.2.9.7, 3.9.6.5), and molding coins or *niska* (*Pam. Vi. Brā.*, 17.1.14).

Śatamāna was clearly a golden (sometimes silver) piece used as medium of exchange of commodities (*Ś. Brā.*, 12.7.2.13; 12.9.1.4):

रजतम् हिरण्यम् दक्षिणा नानारूपतया शतमानम्
भवति शतायुर्वैः पुरुषः
rajatam hiraṇyam daksinā nānārūpatayā śatamānam
bhavati śatāyurvaiḥ puruṣaḥ (*Ś.Brā.*, 13.4.2.10)

V.S. Agrawala (1953:471) observed that the *śatamāna* was mentioned only in the later date *kāndas* (12-14) of *Śatapatha Brāhmaṇa* associated with the name of Yājñavalkya, and therefore most possibly the coin was introduced in the later phase of the *Brāhmana* era (*c.* eight to fifth century BC).

Ś. Brā., 5.5.5.16 subtly explains the function of *śatamāna* : 'with gold they do nothing, and yet it is an object of respect'. Sāyaṇa explains that gold was not used for actual consumption, but only indirectly as a medium of exchange (*Sacred Books of the East*, volume 41, reprint 1963, p. 141). In the same passage, *Ś. Bra.* refers to *trīṇi śatamānāni hiraṇyāni daksinā* — an offering of three golden *śatamānas*. These pieces were circular in shape *pravrttau*, (*Ś. Brā.*, 5.4.3.24 and 26).

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According to the *Vedic Index*, *māna* in Vedic literature was a measure of weight equivalent to the *kṛṣṇala* or *raktikā* (2.152). Thus, the weight of *śatamāna* taken literally would be one hundred *kṛṣṇala*, *raktikā* or *rattis*. *Krsna Yajurveda* recommends (2.3.2.1) *prājāpatyām śatakrsnalām*. *Śatamāna* seems to have decimal as well as binary fractions. A quarter was known as *pāda*: *srṅgayoh daśa daśa padah abaddhāh* (*B.Up.*, 3.1.1). In *Krsna Yajurveda*, 3.4.1.4 (also in *Kā. Sam*, 11.1 and 13.10) *astāprūḍa* golden coin has been mentioned: *astāprūḍa hiranyam daksinā aṣṭāpadi*. This golden coin had eight circular indentations. One-eighth of this money was known as *śāna* in the age of *Mahābhārata* (*Āraṇyakaparva* 134:14) : *aṣṭāyu śānāḥ śatamānam vahanti*. This means that *aṣṭāprūḍa* was another name of *śatamāna*. It may be noted that binary series of weights was found in the Harappan town of Chanhu-Daro. The coins *saṇa* and *karsapana* became popular long after the age of *Saṁhitā* or *Brāhmana* literature.

Manusaṁhitā mentioned that *śāṇa* and other coins could be made of not only gold or silver, but also copper or black metal (iron or lead). We have already referred to the bronze (*AV*, 10.10.5) and lead (*Ś. Bra.*, 12.7.2.10-12) pieces being

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used as media of exchange, *AV*, 5.28.1 mentions in one breath *dīrghāyutvāya śataśāradāya harite trīṇi rajate trīni ayasi trīni.* 'Three pieces (coins) each of gold, silver and *ayas* (bronze?) for worship to gain long life'

Iron Implements

India entered the iron age after the Ṛgvedic era. Many metallic implements, probably made of copper or bronze, were mentioned in our previous chapter on the *Rgveda*. Similar tools continued to be made using the newly discovered metal, iron. We need not mention them again in this chapter. Just by the way of illustration, it may be noted that *kṣura* or razor known in the *Ṛgveda* continued to be popular thereafter (*AV*, 12.5.20,55; *Tait. Sam.*, 2.1.5.7; *Ś. Brā.*, 2.6.4.5; 3.1.2.7; 3.6.2.9, etc.). The 'sharp edge of the razor' *ksurasya dhārā nisitā* (*Kaṭha Upanisad*, 1.3.14, *B.Up.*, 3.3.2) became a popular expression. *Swadhiti* in *Tait.Saṃ.*, 6.3.3.2, *Vā. Sam.*, 2.15 and 5.43 meant an axe or a sword as in *RV*, 2.39.7, 3.2.10, etc.

The names of several new iron instruments appeared in the later Vedic literature; possibly there had been no prototypes in copper or bronze. *Parigha* was an iron bar to keep door(s) closed from inside (*Chā.Up.*, 2.24.6, 10 and 15). It also represented an iron cudgel used in warfare. *Parīṇaha* was an iron chest or *sinduka* for storing valuable items (*AV*, 19.48.1). Two-armed iron tongs was known as *parīśās* (*Ś. Brā.*, 14.1.3.1; 14.2.1.16; 14.2.2.54; 14.3.1); this resembles modern *sandāsī* and was used to lift hot crucibles and vessels from a furnace. *Praśasa* was an axe or some other instrument for cutting (*Ait. Brā.*, 2.6.5, *Nir.*, 5.11). *Śāsa* stood for a sword or knife (*Ait. Brā.*, 7.17.15, *Sānkh. ŚS.*, 15.25.1, *Ś. Brā.*, 3.8.1.4-5, 13.2.3.16). A stick of iron was known as *śalyaka* (*Vā. Saṃ.*, 24.35, *Ait. Brā.*, 3.26.3).

Potteries and other Inorganic Materials

The Vedic literatures were not primarily concerned with either metallurgy or ceramics. Thus we do not find in them the details about two outstanding innovations of that age: iron metallurgy and pottery technology. We hardly get any information about the PGW (Painted Grey Ware) in the Vedic literatures. The *Atharva Veda* (*AV*, 4.17.4) refers to the *āma* (unbaked) and *nīla lohita* ware which is believed to correspond to the earlier black-and-red ware. (Joshi, 1987 : 24-25) Sāyana had explained *nīla-lohita* as: that (pottery) which was made in a fire-kiln where the fire was *nīla* on account of the emission of smoke and *lohita* on account of burning (the combined process of carbonization and oxidization). Hegde pointed out that *ayorasa* or iron rust was used in making the ritual potteries (*S. Bra.*, 6.5.1.6), and whereas hematite is red, in a reducing furnace

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it was converted to blue or rather black magnetite. (Thapar, 1987:415) The reducing atmosphere was provided in an inverted technique of firing in *agnicayana* fire-altar or by some other mechanism.

Baudhāyana Śrautasūtra (9.1-4 and 10.1-8) of *c.* 800 BC described the making of *Pravargya* rite potteries such as *mahāvīra*, the fire-altar (*agnicayana*) and the cauldron (*ukhā*). *Bhāradvāja Śrautasūtra* (*c.* 600 BC) described the polishing of potteries (11.3.9) using cotton cloth and abrasive such as *gavīdhuka*, a very hard wild grain and *klītakā* or *yaṣṭimadhu* blackish paste. (Kashikar, 1969:21 and 26) However all these details pertained to the earlier and archaic varieties of potteries or ritual importance, and did not highlight the recently developed wares such as PGW or NBPW. (Thapar, 1987)

Similarly, we find only casual references to brick-making in the ritual contexts. *Ś. Brā.*, 6.1.2.22 records: 'baking the brick (raw material) amounts to oblation (to god through fire); bricks are produced from what is offered to fire-god (*iṣṭa*), therefore these are called *iṣṭaka* (bricks)'. Glass or faience heads used to decorate the horse's tail during the famous *aśvamedha* sacrifice (*Ś.Brā.*, 13.2.6.8). Mica powder was used as a degraissant in the Harappan potteries. But we do not know whether mica was specifically known as *abhra* in the Vedic literature *Ś.Brā.*, 7.5.2.48 refers to, and defines cloud as *abhra*:

अभ्रम् वा अपाम् भस्म।

abhram vā apām bhasma।

Salt or *lavaṇa* is rarely mentioned in the early Vedic literature such as the *Ṛgveda*. The word appears in the period of the *Brāhmaṇas*. *Ś. Brā.*, 5.2.1.16 recognises salt as an important item of food: 'salt means cattle and cattle is food'. The property of a salt like borax to act as a flux and assist in joining two pieces of gold was known (*Chā. Up.*, 4.17.7, *Jai.Brā.Up.*, 3.17.3):

लवणेन सुवर्णं संदध्यात्।

lavaṇena suvarnaṃ saṃdadhyāt।

One should join gold (pieces) using salt (borax).

The salt from the sea was known as *lohita lavaṇa* or red salt (*Kā.ŚS*, 31.17) and also as *saindhava* or the salt from sindhu or the sea (*B.Up.*, 2.4.12). *B.Up.* further explained in this reference, that when dissolved in water, a salt particle loses its particulate nature and yet imparts salty taste to the entire mass of water:

सैन्धवखिल्य उदके प्रास्त उदकम् एव अनुविलीयेत अस्य उदग्रहणाय इव न ह स्यात्; यतः यतः तु आददीत लवणम् एव . . . .

saindhavakhilya udake prāsta udakam eva anuvilīyeta asya

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udagrahaṇāya iva na ha syāt; yataḥ yataḥ to ādadīta lavaṇam eva
(*B.Up.*, 2.4.12)

Collyrium or *añjana* was another important commodity of common use in the Vedic India. This material was probably black antimony sulphide, applied in the eyes by means of thin 'antimony rods' made of copper, etc. *AV*, 4.9.1-10 eulogizes *añjana* which was available in the *Tri-kakuda* (three-peaked) or *Traikūṭa* mountains (Sulaiman range), in the Himavata (Himalaya) as well as on the Jamunā valley (*AV*, 4.9.10). This material was supposed to protect the user from evil influences and also from various diseases such as tuberculosis, high fever, snake bite, etc. (*AV*, 4.9.4 and 8). Was this also internally administered as a medicine? *Traikūṭa añjana* seems to have become rare in the age of the *Sūtras* which has been hinted in several passages (*Ś. Brā.*, 3.1.3.12, *Kā. ŚS*, 7.2.32).

Shellac or lac was known in the age of the *Atharva Veda* (*AV*, 5.5.1-9) as *lākṣā* or *silācī*. The word *lākṣā* signified *lakhs* of larvae swarming out of a single lac incrustation. The dye component of lac *hiraṇyavarṇe subhage lākṣe* (*AV*, 5.5.7) was used to colour garments. It was also used as medicine in case of injury by weapons (*AV*, 4.12.1-7, 5.5.1-9).

Maṇi in the Vedic Literature

Minerals and gems abounded in the sites of the Harappan civilization and later in Taxilā and the *mahājanapada* sites during the Histrorical Period. Quite strangely however, the Vedic literatures do not mention or name any significant number of minerals or inorganic gems.

Gold and silver were of course mentioned as *maṇi* or *ratna*. *Lohamaṇi* in *Chā. Up.*, 6.1.5 meant red (copper) *maṇi* or bead, and not ruby as some scholars have surmised. The word *maṇi* meant 'anything which decorates'. In the *Atharva Veda*, many plant products such as *jangiḍa* (*AV*, 2.4.1-6), *udumbara*, *darbha*, etc. were stated to be used as decorative *maṇi* to ward off evils.

Gems of organic origin such as ivory, conch-shell, pearl are not usually classified as minerals (which are by definition inorganic); these were used in the Vedic ages as *maṇi*, or gems.

Kā. ŚS, 22.2.22.28 informs that elephants were reared mostly in the eastern part of India, and we have found ivory specimens underneath the early archaeological sites in the Gaṅgā-Yamunā Valley. *AV*, 3.22 refers to the use of ivory.

Conch-shell or *śaṅkha* was used to issue proclaiming sound *śaṅkha dhmāyamānasya* (*ninādit*) (*B.Up.*, 2.4.8; 4.5.9). *Kṛśan* or pearl was possibly

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conch-pearl. The Ṛgvedic poet has described *kṛśan* decorating the chariot of Savitā (*RV*, 1.35.4) and the horses (*RV*, 10.68.1). *Saḍvimśa Brāhmaṇa*, 5.6.13.3 called pearl a *samudramaṇi*. The *Atharva Veda*, 4.10.1-7 discusses the origin of *śaṅkha* and *kṛśan*, as well as their uses as *maṇi* and 'supernatural aids' to ensure long life:

स नो हिरण्यजा: शंख: कृशन: पातुम अहस:
sa no hiraṇyajāḥ śaṅkhaḥ kṛśanaḥ pātuma ahasaḥ
(4.10.1)

दिवि जात: समुद्रज: सिन्धुतस्पर्याभृत:।
स नो हिरण्यजा: शंख आयुष्प्रतरणो मणि:
divi jātaḥ samudrajaḥ sindhutasparyābhṛtaḥ
sa no hiraṇyajāḥ śaṅkha āyuṣprataraṇo maṇi
(4.10.4)

देवानाम् अस्थि कृशनं बभूव . . . वर्चसे बलाय
दीर्घायुत्वाय शतशारदाय कार्शनस्त्वाभि रक्षतु।।
devānām asthi kṛśanaṃ babhūva . . . varcase balāya
dīrghāyutvāya śataśāradāya kārśanastvābhi rakṣatu
(4.10.7)

We find in this passage a mixture of scientific observation and mystical belief. The shell and pearl are said to grow in the sea under atmospheric influences on the one hand; on the other, it is also proclaimed that pearl is god's bone which when worn, ensures a long life.

Conclusion

The Vedic literature primarily deals with philosophy and ritual practices. To some extent it touches upon logic, astronomy and geometry. In the area of materials however, the literature is casually involved. The references to conch-shell and pearl in the *Atharva Veda* show that the maritime trade of the Harappan and Ṛgvedic periods continued to some extent.

The trade gradually dwindled after the collapse of the Harappan civilization and migration of the Ṛgvedic people away from the valley of the Sarasvatī towards the eastern territories. Consequently, the material wealth in the archaeological sites on the Gaṅgā and Yamunā during the pre-historic period did not match with the splendour we find on the valley of the Sarasvatī.

It is quite understandable therefore, that the collection of minerals and gems

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in Hastināpura and Atrañjīkherā (early periods) could not match with those of Harappa, Kālibaṅgan or later-day Taxilā. What is surprising however, is that the Vedic literature does not record some of the genuine material achievements made during its era, such as the discovery of iron, the impressive repertoire of iron implements at Atrañjīkherā, Hastināpura and Kauśāmbī, the technology of glass and pottery such as PGW and NBPW, etc.

The Ṛgvedic bard had a scientific temperament. In the *Nāsadīya Sūkta* (*ṚV*, 10.129), the poet asked questions about the creation and the mysteries of nature. It appears as if in the later period, the Vedic bards lost this scientific spirit, at least in the realm of physical nature. They were infected with the vice of casteist and hierarchical feelings.

At a time when the potters had developed beautiful PGW and NBPW potteries, the *Maitrāyaṇi Saṃhitā,* the *Bhāradvāja Śrautasūtra* (6.8.14), etc. prescribed that the ritual milking pot should be prepared by one belonging to any of the first three social orders, and **not** by a potter! Even metals like gold, copper and newly discovered iron were considered to possess decreasing social status. *Ś. Brā.*, 13.2.2.16-19 describes the *aśvamedha* sacrifice in which a golden knife had to be used for the first order animal namely the sacrificial horse (both representing nobility), copper knife for the *paryaṅgya* or the associate animal, and the *śyāmāyas* or iron knife for the inferior animal ('both representing infantry'). That iron was considered to be inferior than gold and silver becomes evident in *Ś.Brā.,* 13.3.4.5: 'the third (in order) oblation is offered to the people in an iron bowl, for the people are of iron', (that means people are inferior to the king, nobles and the brāhmaṇas). The lower status of potters and ironsmiths in the society reflected a negative attitude towards science and technology, for which India had to pay a heavy price later.

As India entered the Historical Period and developed the *mahājanapadas*, it developed contacts with the Persians, Greeks, and the southern territories of the sub-continent. A new awareness developed in the realms of the material resources, and this was highlighted in the writings of Pāṇini and Kauṭilya, to be discussed in the chapters to follow.

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4

Materials and Concepts in Pāṇini's *Aṣṭādhyāyī*

PĀṆINI'S *Aṣṭādhyāyī* is a veritable store-house of information (Vasu, 1891) on Sanskrit language and ancient India. We learn quite a lot about minerals and metals in ancient India from Pāṇini, who illustrated his grammatical rules by referring to the words of a very great diversity including scientific and technical words (Katre, 1968; vide Appendix 'C').

It is widely accepted that Pāṇini was born at Śalātura which has been identified with Lahur, a small town four miles north-west of Ohind, in the angle of the river Kābul meeting the Indus. The question of Pāṇini's date has been widely debated. Summarising the various arguments, Agrawala (1953: 455-75) has noted that the various dates assigned by scholars to Pāṇini range from the seventh to the fourth century BC, the majority of scholars being inclined towards the fifth and the fourth century BC. Agrawala himself favours a date about the middle of the fifth century BC and suggests that he was a contemporary of the Nanda King named Mahānanda.

The scholars who prefer the later dates presume that Pāṇini's work has not been touched or amended by his followers. This assumption may not be perfectly valid. At least in one case we find that the reference to the Kedara gold coin (Pāṇ. 5.2.120) corresponds to the post-Christian era and therefore could hardly have been made by Pāṇini himself. We may conclude that Pāṇini lived around 500 BC near the ancient city of Takṣaśilā or Taxilā after this was founded under the Achaemenid influence.

The second urbanisation in India started around the early part of the first millennium BC. Settlements grew into small kingdoms or *janapada* about which an early reference is available in *Chāndogya Upaniṣad* (5.11.5). There must

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have been a boost to mining and metallurgy in the north-western part of India after the partly successful intrusion of the Persians into India during the later half of the sixth century BC. Pāṇini's work reveals the contemporary awareness and activities in the fields of (a) mine and mineral engineering, (b) extractive metallurgy, (c) minerals and inorganic compounds, (d) metals, (e) coinage metals besides the development of several other technical and scientific concepts.

Mine and Mineral Engineering

Pāṇini recognised that the word *khan* or to dig (well, mine etc.) had appeared in the *Chandas* or the Vedic literature. He explained (3.2.67) the genesis of the derivative words *ākhanika* and *khanitra* meaning a spade. *Maṇi-prastāra* (3.3.32) or scattering or vein of gems was recorded as an important mineralogical information. The commercial importance of mining during Pāṇini's time is revealed from his discussion on *ākarika* (4.3.75) which meant miner, mining officer as well as mining revenue.

Utilisation of big-size rocks containing specific minerals involved size-reduction and purification and, in the case of metal extraction, certain steps in process metallurgy. *Jambhaka* (7.1.61) alluded to crushing using jaw which reminds us of the modern-day jaw crusher. Further size reduction or grinding *peṣam* could be done under dry condition (*śuṣka / rūkṣa / cūrṇa*) or under wet condition (*udpeṣam*) (Pāṇ., 3.4. 35-38, 6.3.58, etc.). Crushing resulted in small particles of different sizes and densities, and therefore these were separated (or purified) from each other by several technique including winnowing or *paripavana* (8.4.34). Winnowing is a pneumatic (air) separation/purification technique exemplified in the traditional separation between rice and husk. *Pavana* means air and *pāvaka* means purifier. There seems to be an etymological relationship between the two words.

Extractive Metallurgy

An ore is defined as a metal-bearing rock from which metal may be extracted by process or extractive metallurgy. The art of making copper from its ore was known in the Pre-Harappan age, and iron-making was discovered around 1200 BC. The Vedic literatures contain references to blacksmiths or *kārmāra* blowing air (*dhma*) in a furnace. The *Śatapatha Brāhmaṇa* mentions *bhastrā* merely as a leather bag. Pāṇini explains for the first time, the use of leather bellows in a furnace for blowing air into it. A furnace may have more than one bellow in which case it is called *bahubhastrikā* (7.3.47). Bellow pipe and pair of bellows with nozzles have been found in the Parthian stratum in Sirkap during the excavations at Taxilā.

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The word *bhraṣṭṛ* in Pāṇini' *Aṣṭādhyāyī* 6.4.47 and 8.2.36 — meaning 'one who roasts' — suggests that sulphide ores were probably roasted before smelting. *Samid-dṛṣada*, fuel stone or firewood was mentioned by Pāṇini (5.4.106). Was it coal or lignite by chance, or some plain hard firewood? Probably it was used in the metallurgical furnace. The scholars who do not have metallurgical background may have difficulty in appreciating the link between the words *pūta* (cleaned, purified) and *pūti* (foul smelling, putrid, stinking). Copper and other sulphide minerals were purified (*pūta*) in the furnace or smelter which produced foul furnace (*pūti*) smell (*gandha)* of sulphur dioxide. Thus, the sulphide smelting furnace could be called *pūtigandhi* (Pāṇ., 5.4.135). Crude metal was further purified in crucibles. Pāṇini does not seem to mention *mūṣā*, the Indian word for crucible, which appeared in the post-Pāṇini literatures. However, Pāṇini mentioned *sruva* or ladle (6.3.115) from which liquid gushes out, and might have observed molten metal being poured from a ladle for the operation of casting in mould.

Minerals and Metals

In the Vedic literatures, the word *maṇi* was used in a general sense indicating anything 'which decorates'. Quite a few materials of organic origin were known and used: ivory, conch-shell, coral, pearl, etc. In Pāṇini, we find the mentioning of several colouring agents — some organic dyes such as *raucanikā*, *haridrā*, *lākṣā* (known even earlier), *kajjala* or lamp black, etc. and some inorganic pigments such as *rocanā* (4.2.2) which is probably yellow arsenic sulphide, called orpiment.

Lohitaka (red) and *sasyaka* (blue gem) are mentioned by Pāṇini (5.4.30 and 5.2.68). The most interesting reference about a mineral in Pāṇini is related to cat's eye, beryl or *vaidūrya*. In 4.3.84 Pāṇini states that the minerals came from the city of Vidura, and that is how the word *vaidūrya* (originating in Vidura) was derived. Later, it was stated by Patañjali that the mines of *vaidūrya* were in the mount Vālavāya, but the gem was cut in Vidura (*Bhāṣya*, 4.3.84; 2.3.13). We are not sure about the location of Vālavāya mountain. This was probably in the Deccan. Pāṇini had geographical acquaintance down south up to the site of Aśmaka on the river Godāvarī. The city of Vidura was probably in the Vidarbha region in Madhya Pradesh. The pale green gem mineral *vaidūrya* became one of the most precious items adored by the Indians.

Pāṇini explained in 5.4.94 that *ayas* stands for metal in general, but when qualified, it could mean a specific metal such as *kālāyasa*, black metal or iron, *lohitāyasa*, red metal or copper. Thus *ayas* was taken both as a genus (*jāti*) as well as species (*saṁjñā*). Unless qualified otherwise, *ayas* sometimes meant

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iron. The world *lauha* meaning iron evolved much later. It could have originated either from *loha* (red) meaning that which is extracted from the red ore of hematite; alternatively, it could have been a verbal derivative from *lu* which means to cut, sever, or divide, *lauha* meaning something which cuts, severs or divides. The second postulate receives some support from the fact that *lavitra* meaning a sickle (3.2.184) is related to the verb *lū*.

Another word related to *ayas* is *ghana* or *ghna*. *Ghana* means compact, solid, hard, firm, dense (Pān., 3.3.77-78). Pānini continues in the text 3.3.79-83 to explain that *ghana* is often used as *ghna* or *han*, meaning one which destroys or deforms. In this sense, *ayoghana* or *ayoghna* meant forge hammer or sledge hammer (3.3.82), *udghana* carpenter's bench, *vighana* hammer or mallet, *drughana* an axe (3.3.82) *stambaghana* meaning small hoe for weeding clumps of grass and so on. A related word, *parigha* (3.3.84) or *parighana*, earlier used in the Vedic literatures, meant an iron beam used for locking or shutting the gate or an iron club. From the word tongs (*kutilikā*), the blacksmith, *karmāra* was also known as *kautilika*. Whereas *ayasmaya* meant metallic (1.4.20), *ayo-vikāra* stood for iron fabric (4.1.42) and *āyah-śulika* meant iron spike (5.2.76).

Pāṇini mentioned that the words *lohitāyasa* (copper), *trapu* (tin), *kāṅsya* (bronze or bell metal) had been used in the Vedic literatures. A newly defined term *trāpusam* meant modification or *vikāra* of *trapu*, i.e., an alloy of tin, just as *jātusam* meant modification of *jatu* or lac (Pāṇ., 4.3.138). This shows that tin and bronze (copper-tin alloy; *kaṁsa*) were commonly used during Pāṇinī's time. Whether *kaṁsa* meant brass (copper-zinc alloy) also, is not known. Possibly brass became popular in Taxilā after the instrusion of the Greeks. *Ghosa* came to mean bronze long after Pānini's time. Pānini was probably the first to mention the word *kupya* indicating base metal other than gold and silver (3.1.114).

Gold and Coins

The goldsmith was known as *svaranakāra*, who made **ornaments** as well as coins of gold and silver. Pāṇini referred to some special ornaments; ear-rings (*karṇikā*, later the famous term *manikarnika* associated with Vārānasī), frontlets (*lalatika*), finger-rings (*aṅguliyaka*) (4.3.62-65), etc. *Ākarṣika* was one skilled person who could test gold on the touchstone (*ākarsa*, 5.2.64). The goldsmith undertook three kinds of jobs. (Agrawala, 1953:235) He could start with new gold or silver bar or ingot brought to him. Secondly, he could melt and re-shape old ornaments: *nistapati suvarnam*. Thirdly he could repolish or brighten the old ornaments by heating them only once (*anāsevane* : Pāṇ., 8.3.102).

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The earliest historical record of the Indian coins is found in Pāṇini's *Aṣṭādhyāyī*. We have noticed that the Vedic literatures mentioned the golden *niṣka*, sometimes as an ornament and sometimes as a medium of exchange. We postulate that the word *niṣka* was etymologically related to the word *niṣaya* mentioned by Pāṇini to indicate binding, meaning financial bond or commitment. Pāṇini referred to several derivative terms based on *niṣka*: *dviniṣka* (two *niṣka* or units of money), *bahunaiṣkikam* (worth many *niṣkas* — Pāṇ., 5.1.30), *uttamanaiṣkikam* (worth the highest *niṣka* or denomination of money — Pāṇ., 5.1.20). Gold was known as *jātarūpa*, 'beautiful when it appears'. Pāṇini forwarded a linguistic hypothesis (we are not sure of its validity) that all words for gold indicating weight or measure (of money) end with *aṇ* e.g. *suvarṇa*, *swarṇa*, *hiraṇya*, etc.

जातरूपेभ्यः परिमाणे अण्

jātarūpebhyaḥ parimāṇe aṇ (Pāṇ., 4.3.153).

Similarly when a weight of copper was used as coin, it was known as *paṇa* : *paṇaḥ parimāṇe* (Pāṇ., 5.1.34).

Pāṇini also explained the genesis of the word for silver : *rūpyaḥ* or *raupya*. Next to gold, silver was used as the coinage metal. Some form (*rūpa*) of the king or ruler was embossed (*āhatam*) : *rūpāt, āhata, praśaṃsayoḥ yap* (Pāṇ., 5.2.120). Thus *raupya* was derived from *rūpa* and became the new name of *rajata* or silver during the Achaemenid rule (sixth century BC). There was a special name for a stamped or embossed silver coin *vārk rūpya* or silver stamped with *vṛka* die (Pāṇ., 4.2.106).

Śatamāna to *Kārṣāpaṇa*

V.S. Agrawala (1953:471) pointed out that *śatamāna* as a coin had been mentioned in the *Śatapatha Brāhmaṇa* only in those *Kāṇḍas* (5 and 12-14) associated with the name of later day sage Yājñavalkya. Thus this currency probably existed during the latter part of the *Brāhmaṇa* era (*c.* eighth-fifth century BC). Pāṇini witnessed the transition of the Indian coinage system from the *śatamāna* to the *kārṣāpaṇa* denomination. Pāṇini also mentioned a gold coin *vista* of 80 *rattis* or *ratikās* (Pāṇ., 4.1.22; 5.1.31).

Śatapatha Brāhmaṇa (13.4.2.10) made it clear that both gold as well as silver *śatamāna* coins were in circulation. No gold *śatamāna* has been discovered; probably all such objects were ultimately melted and re-used for some other purpose.

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The heavist silver punch-marked pieces so far discovered are the oblong bars in the Bhir Mound at Taxilā assignable to the middle of the fourth century BC. These are twice as heavy as the Achaemenid or Persian *siglos*. Weighing around 180 grains or 100 *ratti/māna/krṣṇalas*, the Taxilā bent bar coins (*śalākā*) probably represent the ancient *śatamāna* coins (Pāṇ., 5.1.27).

The most important (one-eighth) fraction of *śatamāna* was a *śāṇa* (*Mahābhārata*, *Āraṇyakaparva*, 134.14). Pāṇini refers to the silver coin *śāṇa* in several places (5.1.35-36; 7.3.17). He refers to certain taxes levied in East India (6.3.10), on which the Kāśikā cites *sūpeśāṇah* (6.2.64 and 6.3.10) — a special cess at the rate of one *sāna* coin per kitchen (*sūpa*) or household.

The *kārṣāpaṇa* monetary system started around sixth century BC probably as a standard for collecting *kara* or tax, toll and royal revenue (Pāṇini, 5.1.29 and 6.3.10). The word *kārṣāpaṇa* is unknown in the *Saṃhitā* or *Brāhmaṇa* literature, and is peculiarly a Sanskrit term of the *Sūtra* period. (Agrawala, 1953:264) Numerous hoards of this punch-marked coin, also known simply as *paṇa*, have been found in various parts of India. The sub-multiples of *kārsāpaṇa* were known as: *ardha* (1/2), *pāda* (1/4), *dvi-māṣa* (1/8) , *māṣa* (1/16) and *ardha-māṣa* or *kākaṇī* (1/32) and *ardha-kākaṇī* (1/64). Pāṇini mentioned part of this series in 5.1.34: *paṇa-pāda-māṣa-śatādyāt*. *Pāda* means a quarter, and there had been *pāda-niṣka* or *panniṣka* coins in the Vedic age. In Pāṇini 5.1.34, *pāda* meant quarter of a *kārṣāpaṇa*.

Māṣa in the above *sūtra* was both a silver and a copper coin. The silver *māṣa* was one-sixteenth of a *kārṣāpana* and weighed 2 *rattis* or 2 *krṣṇalas* or 3.6 grs:

द्वे कृष्णले समधृतो विज्ञेयो रौप्य-माषकः
dve kṛṣṇale samadhṛto vijñeyo raupya-māṣakaḥ
(Manu, 8.135).

Actual specimens of silver *māṣa* coins have been found in a hoard at Bhir mound, Taxilā. These are minute coins, 0.2. inch diameter weighing 2-3 grains.

The copper *māṣa* was a sub-multiple of the copper *kārṣāpaṇa* and weighed 5 *rattis*, i.e., one-sixteenth of a *tāmrika-paṇa* of 80 *rattis*. The *kākaṇī* and *ardha-kākaṇī* copper coins were not mentioned by Pāṇini, and became common later during the period of Kauṭilya.

The silver *kārṣāpaṇa* of 32 *rattis* was upgraded by the Nandas. Instead of 16 *māṣa kārṣāpaṇa* they introduced heavier 20 *māṣa* silver coin which came to be known as *viṁśatika*. Pāṇini mentioned (5.1.24) *viṁśatika* as well as the 30 *māṣa triṁśatika* coins being in circulation.

We have mentioned Pāṇini's explanation as to how the word *raupya* for silver

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originated: on a silver coin the *rūpa* or form of the king was embossed. "The mode of manufacturing the punch-marked silver coins was first to get ready a hammered sheet, which was then cut into strips, and sub-divided into lengths of approximately the desired weight, which was adjusted by clipping the corners when necessary". After this, the metallic pieces were subjected to the process of stamping symbols on them by means of a separate punch for each symbol. It is this particular stage in the process of manufacture to which Pāṇini refers in the famous *sūtra*:

रूपात् आहत प्रशंसयोः यप्

rūpāt āhata praśaṃsayoḥ yap

(5.2.120)

'Silver was stamped with a praise-worthy form'.

Whereas *kārṣāpaṇa* was a punch-marked coin, the later day *dīnāra* (Denarious) and kedāra (*Kedāra* Kuṣāṇa coin third century AD) were actually cast in moulds and not punched.

Concept of Unit Operations

The modern terminology 'unit operation' means the physcial step(s) which are important pre-requisites towards purification and preparation of materials with or without some chemical change termed as 'unit process'. Pāṇini's India was familiar with quite a few unit operation principles.

Drava (Pāṇ., 3.3.27) meant melting or something which can be melted. Few more words were also used to denote melting: *pralaya* (melting, losing shape, dissolution — Pāṇ., 7.3.2), *vipātana* (melting of *loha* or copper, *sneha* or fat — Pāṇ., 7.3.39), etc. *Sru* meant (for liquid) to flow or gush out (Pāṇ., 7.2.13) and the derivative *sruva* (6.3.115) an object like a ladle, from which liquid gushes out.

The opposite of *drava* (melting), *pralaya* (losing shape) and *sru* (to flow) was reckoned as the phenomenon of a molten object or liquid becoming frozen (*śīta*, 6.1.24-26) or solidified (*mur*, 6.4.21). From *mur* was derived *mūrtta* and *mūrti*, the phenomenon of assuming shape which is possible only for a solidifying object. Coagulation is the aggregation of dispersed phase in a heterogeneous system not necessarily accompanied by loss of heat, as exemplified in coagulation of the protein matter from milk. This phenomenon of coagulation (*śīna* — coagulated) was distinguished from the process of being frozen (*śīta*) on account of cooling (Pāṇ., 6.1.24-26).

It was realised in ancient India that preparation of material such as *soma-*

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juice, *surā*, gold, copper, etc. often involved separation from impurities or purification. The first two alphabets in 'pure', namely *pu* meant 'to purify'. The link between the European word and the Sanskritic origin is so obvious. *Pūta* meant 'cleaned or purified' (Pāṇ 6.2.187), and *pāva* stood for 'purifying, clarifying or cleaning' (*Pāṇ.*, 3.3.28 and 49). The words derived from *pāva* strongly suggest **how** a particular kind of purification may take place. *Niṣpāva*, for example, stands for winnowing as well as a step of purification which involves (*ni* or) downward movement. We have explained that winnowing does involve differential downward movements of particles of different sizes and densities.

Utpāva meant a purification step involving some kind of ascent which is implicit in evaporation (upward escape of water vapour from *ghī* being purified through heating over fire — Paṇ., 3.3.49) and distillation (in which the escaping vapour is condensed to yield pure liquid as in the case of alcohol, mercury, etc.). The idea of vapour **going over** for subsequent condensation was reflected in the word *pārāyaṇa* (5.1.72). Although Pāṇini did not state 'distillation' as one of the meanings of *pārāyaṇa* (going over), and did not refer to *pārā* or *pārada* (mercury, which is purified by distillation), the link between the words is quite obvious.

Pāṇini mentioned that the word *kṣariti* means to flow, break away, glide or to distil (7.2.34). The basic idea was the transport of one component or its migration from another. (*Akṣara* meant the opposite of removal, i.e., that which is indestructible). Pāṇini categorically mentioned *kṣara* to mean distillation and *kṣaraja* to mean a substance produced by distillation (Pāṇ. 6.3.16).

Allchin (1979) mentioned India as 'the ancient home of distillation'. The earliest literary reference related to *kṣara*, *yaṃ . . . na viśvadhakṣaradhyai* (*Ṛgveda,* 1.63.8) refers to rain-water being discharged by Indra all over the world, and clearly alludes to the later part (condensation) of distillation. Pāṇini referred to a distiller as *śauṇḍika* (4.3.106), the word alluding to intoxication rather than the distilled product causing it.

Apart from distilling alcohol or *surā*, the ancient Indians of the pre-Christian era most probably distilled mercury and zinc also. In Taxilā certain artefacts unearthed look like distillation outfits. Vermillion (assaying 85 per cent plus mercuric sulphide HgS) found in Taxilā might have been used not only as a pigment but also to produce mercury by distillation. A brass vase assaying 34.34 per cent zinc (Marshall, 1951: 568) could not be obtained by the cementation process; zinc metal for this must have been prepared separately by a distillation process. It is significant that while mercury was later mentioned as *rasa*, zinc came to be known as *rasaka*, probably implying the 'juice' which is obtained like *rasa,* by a similar process (of distillation).

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Certain unit operations, though not practised in the area of minerals and metals, were very useful in terms of food processing. We have indicated that winnowing or *niṣpāva* using a winnow or *śūrpa* was widely practised in the ancient India, starting from the Harappan age, for separating grain from husk. *Niṣkoṣana* meant extraction in the sense of husking shelling of grains, disembowelling, de-seeding of fruits, etc. (Pāṇ., 5.4.62). Such a technique was used for removing the cortex from agate mineral grains also. *Su* and *āsu* meant to press out the juice from materials like *soma* plant-stem and tendril, and the oil from the vegetable oil-seeds (Pāṇ., 3.1.126; 3.2.103; 7.2.72, etc.). After squeezing the juice out, it was necessary to strain or filter the *soma*-juice, etc. free from suspended solids. Wire-mesh, fibre-mesh or cloth was used as a filtering medium. Such a step of purification was known as *prapavana* (Pāṇ, 8.4.34), this word being one more in the series derived from the base *pu* meaning purification.

Technical Concepts in *Aṣṭādhyāyī*

Pāṇini's *Aṣṭādhyāyī* contains references to not only the uses of materials, such as minerals and metals in ancient India, but also to the mode and rationality of the said uses. Besides the unit operations, several thought processes or technical concepts were illustrated.

Pāṇini elevated his work on grammar to the level of a **science** of languages, explaining in great detail the verbal and other kinds of roots of large number of Sanskritic words. He never lost objectivity and admitted that some words were coined accidentally and did not have any clear root. The surprising thing is that he could discover the *dhātu* (root or constituent) of such a large number of words.

Padārtha originally meant the meaning (*artha*) of a word (*pada*) and very soon came to denote a thing, material or object whose name conveys a district meaning or a material which is well-defined (Pāṇ., 1.4.96). Thus Pāṇini brought us from the linguistic to the material science. During Pānini's time, *dhātu* meant the constituent, and later it denoted metallic constituent or a metal. *Sattva* meant reality, substance or the **essence** of an object (Pāṇ., 1.4.57; 2.3.33). The *Rasa-Śāstras* of the post-Christian era adopted the word *sattva* to mean the metallic essence in the ore mineral(s).

Pāṇini's outstanding deliberation on words denoting concepts, shines brilliantly in several instances, e.g., *pramāṇa*, *upajñā* and *upakrama*. *Pramāṇa* originally meant (and still means) a standard or scale for measurement and therefore an 'authority' (Pāṇ., 3.4.51; 4.1.24; 5.2.37; 6.2.4 & 12). Gradually the idea of 'proof' originated from the notion of authenticating an object or an idea through its reference to a previously accepted yardstick or an axiom (*pramā* means

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basis or foundation). Thus *pramāṇa* came to mean a scientific or logical proof.

Notwithstanding the dogmatic belief of some traditional scholars in the 'infallibility' of the *Vedas* which are supposed to be the 'repositories of **all** knowledge', the non-traditional scholars of the ancient India adored *upajñā* and *upakrama*. Pāṇini honoured this tradition of searching for truth by explaining that *upajñā* meant discovery or invention by one's self, a new knowledge **not** handed down by tradition. This newly acquired knowledge in its turn gives rise to a new enterprise or application, that is *upakrama* (Pāṇ., 2.4.21; 4.3.115 and 6.2.14). Even the modern science and technology rest upon the conceptual trinity of *pramāṇa*, *upajñā* and *upakrama*.

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5

Minerals and Metals in *Kauṭilīya Arthaśāstra*

Kauṭilīya Arthaśāstra is a store-house of information regarding minerals and metals in ancient India of the pre-Christian era. Before we discuss the technical details in this post-Pāṇini document, the controversy surrounding its authorship and date should be briefly mentioned.

Different theories have suggested different dates for the *Arthaśāstra* ranging from the fourth century BC to the third century AD. (Kangle, 1986; Mukherjee, 1987) Most scholars however accept the traditional view that Kauṭilya, also known as Cāṇakya or Viṣṇugupta, who destroyed the power of the Nandas and placed Candragupta Maurya on the throne of the Magadha, is the author of this work. Candragupta came to the throne around 321 BC, and therefore it may be presumed that the work was undertaken and completed in the later half of the fourth century BC. Although clear statements are found to the above effect in the text (1.1.19 and 15.1.73), doubts have persisted.

We have the following strong arguments favouring the traditional view: (a) the traditional view has been endorsed by many subsequent authors of the ancient India such as Kāmanḍaka (author of *Nītisāra*), Daṇḍin (author of *Daśakumāracarita*), Bāṇa (author of *Kādambarī*), etc.; (b) *Arthaśāstra* must have preceded two pre-Christian era texts, the *Smṛti's* of Manu and Yājñavalkya who reproduced extracts from the *Arthaśāstra*; (c) *Ajivakas,* mentioned in the *Arthaśāstra* (3.20.16), the Lokāyata philosophy (1.2.10) and several oligarchies (referred therein 11.1.4-5) disappeared from the Indian scene by the third century BC; (d) unlike the later-day *Rasa-śāstra* texts, the *Arthaśāstra* mentions 'liquid ore', *vaikrantaka* — a metal, and refers to tin as *trapu* and not *vaṅga*, and to brass as *ārakūṭa* and not *pittala*; (e) the tradition of punch-marked coin

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overseen by *lakṣaṇādhyakṣa* (2.12.24) was a pre-Greek tradition (the Greek tradition being engraving of ruler's effigy or the casting of coins in moulds); the counterfeiter used to strike his coins with the help of a hammer and a die bearing design after blanching the blanks in alkalis (4.4.20), since the cheaper process of casting was not yet (third century BC) in vougue.

Weighing various arguments, H. Jacobi concluded and counselled: "without weighty arguments, one must not push aside the unanimous Indian tradition" (regarding the authorship and date of the *Arthaśāstra*). We are therefore on reliable grounds while placing *Arthaśāstra* in the early Maurya era of the late fourth century before Christ.

The test starts (1.2.1) with the premise that four types of knowledge-investigative philosophy, Vedic religion, economics and the science of politics — sustained the welfare of the Indian society. *Artha* is the sustenance or livelihood (*vṛttih*) of men. From the word *vṛtti* is obviously derived *vārttā*, the threefold economic activity of agriculture, cattle-rearing and trade (1.4.1). The emerging diversity of arts and crafts (1.3.8; 2.6.2) was also recognised. The means of ensuring the pursuit of philosophy, the Vedic religious life and the economic prosperity is a disciplined and just administration, ever willing to protect the weak and punish the violators of law (1.4.3-16). An ideal state should encourage private initiative, according to the *Arthaśāstra*, but under strict administrative control exercised by a central authority. The section on the tariff of duties and tolls (2.22.1-15) suggests that all spheres of economic activity had to be strictly monitored by the state.

Mines and Metals in the Society

Mines were considered to be of supreme importance towards the economic welfare of the society and defence of the nation against external aggression. One of the most crucial statements in the *Arthaśāstra* reads:

> आकरप्रभवः कोशः कोशात् दण्डः प्रजायते।
> पृथिवी कोशदण्डाभ्याम् प्राप्यते कोशभूषणा।।
> *ākaraprabhavaḥ kośaḥ kośāt daṇḍaḥ prajāyate ।*
> *pṛthivī kośadaṇḍābhyām prāpyate kośabhūṣaṇā ।।*
>
> (2.12.37)

> The treasury has its source in the mines; from the treasury the army comes into being. With the treasury and the army, the earth is obtained with the treasury as its ornament.

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Thus mines have primordial importance. It has been stated more explicitly (7.14.25) that 'mines are the source of implements of war':

खनिः संग्रामोपकरणानां योनिः।

khaniḥ saṃgrāmopakaraṇānāṃ yoniḥ ।

Gold, silver, diamonds, gems, pearls, corals, conch-shells, metals, salt and ores derived from the earth, rocks and liquids were recognised as materials coming under the purview of mines (2.6.4). The Superintendent of Mines was supposed to be an expert in mineralogy, smelting and colouring gems (2.12.1) and to establish factories for the above items and also derivatives like the caustic alkali (2.12.27). The metallic ores had to be sent to the respective Metal Works for producing 'twelve kinds of metals and commodities' (2.12.23 & 35-36). From the mines and the metal works had to be collected 'the price, the share, the surcharge, the monopoly tax, penalty, duty, compensation, fine, inspection fee and manufacturing charges' (2.12.35-36). Thus the state was supposed to have complete control over the mineral resources.

Indian Topography of the Mineral Resources

The *Arthaśāstra* clearly reveals that the then India was no longer a cluster of small-sized states, but had grown to be a big nation. Earlier accustomed to the trade-routes across the Himalayas, the North Indian empire now opened up its trade-links with the South, specially to acquire pearl, conch-shell, diamond, ruby and gold (7.12.22-24). The South was the land of the sandalwood (2.11.43). The best elephants and therefore best ivory came from the east viz, Aṅga and Kaliṅga (Assam and Orissa) (2.2.15).

Gems and pearls came from the Mountain Malayakoṭi in the Pāṇḍya kingdom, river Cūrṇī in Kerala and 'even from beyond the sea' *pārasamudraśca*, i.e., Sri Lanka, its river Kulā near Mayuragrāma (2.11.2 & 28).

The state maintained its shipping boats or *rājanau*, and these could be utilised by the traders and those fishing for conch-shells and pearls, against suitable payment (2.28.4-5). The boats plied on the trade-route along the coast instead of moving into the high sea (7.12.21). The references to the import of red coral from Alexandria (2.11.42) and the worship of the Mahākaccha or the Gulf of Cutch before the naval journey (4.3.12 & 15) authenticate the Indian maritime trade with the Persian and Mediterranean Sea countries.

The Director of Mines — His Duties

The Director of Mines or *Ākarādhyakṣa* was supposed to be an expert in

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śulvaśāstra or the mineralogical (and water) veins in the rock (2.12.1; 2.24.1). He could open a new mine or tap, the residual ore from an old mine, detected 'by the marks of dross, crucibles, coal and ashes' (2.12.1). In case of some useful information about mines, gems and buried treasures, the informant was supposed to receive one-sixth part, and in case he happened to be a state employee, only one-twelfth part (4.1.51) of the treasure.

The *Arthaśāstra* advised the Director of Mines to concentrate on the more accessible mines needing less capital investment and yielding large quantities of commodities and large profit over a number of years. The temptation for mining highly valuable gems should be controlled since such materials were rarely obtained in large quantities in one place, and the buyers were few and rarely available (7.12.13-16, 25 & 31). We may recall Pliny's comment (31.39) in this context that the Salt Range supplied more revenue to the king than gold and pearls.

Burdensome mines may be leased to individuals, but otherwise all large-profit mines and metal works should be operated by the state itself. All transactions — buying and selling — of minerals and metals — had to be executed with the state only (2.12.19; 2.22.10). The defaulters and other criminals were forced to labour in the mines. Salt works based on sea water could be lease-rented, but the state had to collect its share of crystal outcrops and fix the price (1.13.21; 2.12.18-22, 27-28 & 32).

Gem Minerals

Maṇi-dhātu or the gem minerals were characterised in the *Arthaśāstra* as 'clear, smooth, lustrous, possessed of sound, cold, hard and of a light colour' (2.12.17). An excellent gem was supposed to have some specific shape-hexagonal, square or round — a flashing colour, a suitable form, and to be clear, smooth, heavy, lustrous, with lustre inside and imparting lustre (2.11.33). With a dull colour and lustre, with grains, with a hole in the bloom, broken, badly bored, and covered with scratches — these were considered to be the blemishes of gems (2.11.34).

Pearls or *muktā* originated in the oyster-shells and conch-shells, and were available in the Tāmraparṇī (Tinnevelly or Tuticorin), Pāṇḍyaka-vāṭa (the Pāṇḍya kingdom), etc. (2.11.2-3). Excellent pearl gems had to be big, round, without a flat surface, lustrous, white, heavy, smooth and perforated at the proper place. The defective ones were lentil-shaped, triangular, tortoise-shaped, semi-spherical, with a layer, coupled, cut up, rough, spotted, gourd-shaped, dark, blue and badly perforated (2.11.4-5).

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A large variety of pearl-strings to be used for the head, hands, feet and waist were described (2.11.6-27):

Śīrṣaka (for the head, with one pearl in the centre, the rest small and uniform in size), *avaghāṭaka* (a big pearl in the centre with pearls gradually decreasing in size on both sides), *indracchanda* (necklace of 1008 pearls), *māṇavaka* (20 pearl string), *ratnāvalī* (variegated with gold and gems), *apavartaka* (with gold, gems and pearls at intervals), etc. Ivory was known as *danta* (3.17.8).

Good *pravāla* or corals (colour of the red lotus) came from Ālakandakam (Ālasandrakan in another manuscript; this is most possibly Alexandria of Egypt) and Vivarna (African coast of the Red Sea and Sicily, Sardinia). The specimens eaten by insects and bulging in the middle were not accepted (2.11.42). It may be noted that red coral (*corallium rubrum*, family *Gorgonidae*) of the Mediterranean was as popular to the Indians as white pearl at Rome (Pliny, 32.11). Before the Indo-Roman trade began, India was probably receiving this material through the Arab and Persian traders.

Diamond (*vajra*) was discovered in India of the pre-Christian era. The *Arthaśāstra* mentioned several sites of origin in Sabhārāṣtra (Vajragṛha or Wairagadh in Vidarbha), Tajjamārāṣṭra (Orissa), Kāstīra (Katni?) and observed that this precious gem could come from the mines, streams or placer deposits (2.11.37-38). Sometimes confused with cat's eye, quartz or some other gem (2.11.39), a good sample of diamond had to be:

स्थूलं गुरु प्रहारसहं समकोटिकं
भाजनलेखि तर्कुभ्रामि भ्राजिष्णु च प्रशस्तम्

sthūlaṁ guru prahārasahaṃ samakoṭikaṃ
bhājanalekhi tarkubhrāmi bhrājiṣṇu ca praśastam

(2.11.40)

Big, heavy, capable of bearing blows, i.e., hard, with symmetrical points, (capable of) scratching a vessel, i.e., abrasive, revolving like a spindle (scattering incident light) and brilliantly shining.

Such is an excellent (*praśasta*) sample of diamond; that with points lost, without edges and defective on one side is bad (2.11.41).

The author of the *Arthaśāstra* did not possess our present-day knowledge of elements and their compounds, and thus could not present any sophisticated classification of gem-minerals. His classification was naturally based upon colour and lustre. Such a classification, made in the ancient world, inevitably resulted in considerable confusion since radically different kinds of gems

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sometimes possess similar colour, and very small quantities of impurities often alter the colour of the gem radically. Thus, the correlations between the ancient and modern nomenclature of gem-minerals are at best tentative. Archaeologically derived samples may however be subjected to modern instrumental tests for confirmation.

The *Arthaśāstra* described certain types of generic names of minerals (2.11.29-32):

red *saugandhika*, green *vaidūrya*, blue *indranīla* and colourless *sphaṭika*.

Although red *saugandhika* (2.11.29) was considered to be a basic variety of gems (*Bṛ. Saṁ.*, 82.1) in the early centuries, later it was included under the category of ruby, which is *padmarāga* (colour of red lotus) or *māṇikya* (Manasollāsa, 2.475-6).

Ruby is the clear red variety of *kuruvinda* (2.14.48) or corundum (Al_2O_3) containing chromium and a little iron; this is known in India as *padmarāga*, *māṇikya* or *cuṇī*. Balas-ruby is rose-red and was known as *bālasūryaka* (like the morning sun). This spinel probably came from Badakshan. Rubicelle, which is yellow, was known as *karuṇḍaka*. Deep red spinel or spinel ruby $MgAl_2O_4$, identified with *saugandhika*, actually belongs to a different (spinel) family of minerals. Many other classess of gems could have red colour.

The green beryl or *vaidūrya* (2.11.30) has been earlier mentioned by Pāṇini in his *Aṣṭādhyāyī* (vide previous chapter). The accounts of the Greek and Roman travellers, as well as the numerous references in the Indian epics, describe in glowing terms the Indians' abiding fascination for *vaidūrya*, whose colour has been aptly compared with sea water, green bamboo and parrot's wing:

उदकवर्णो वंशरागः शुकपत्रवर्णः
udakavarṇo vaṁśarāgaḥ śukapatravarṇaḥ
(*Arthaśāstra*, 2.11.30)

Beryl is beryllium aluminium silicate with some substitution of beryllium atoms by Na, Li or Cs. Some substitution by chromium makes it bright green emerald, which has been known in India as *marakata* or *pannā* (not mentioned in the *Arthaśāstra*). *Pannā*, the famous Indian site of diamond in the Madhya Pradesh, might have yielded some emerald (*pannā*) in the past. The bluish green variety of beryl is known as aquamarine or *pāribhadra*, and was mentioned in the *Arthaśāstra* as *uptpalavarṇah* (like blue lotus). The yellow variety *puṣyarāga* (yellow like turmeric) (2.11.30) could correspond either to golden beryl (heliodor) or to *puṣparāga*, an altogether different kind of mineral viz., topaz, which is aluminium fluorosilicate. *Gomedaka* (2.11.30) was probably brown zircon or

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garnet. Another variety, chrysoberyl ($BeAl_2O_4$) is pale greenish yellow and looks like cat's eye or *mārjārakṣaka* which is mentioned in the *Arthaśāstra* under a different context related to diamonds (2.11.39).

Section 2.11.31 describes *mahānīla* (deep blue) *indranīla* (sapphire, which is corundum or Al_2O_3 containing Ti, Fe and Co as impurities), a variation being asteriated or star, sapphire entiled *sravanmadhya*, bluish gem 'having rays shooting like flowing water'. Later *mahānīla* was distinguished from *indranīla* in the text Agastimata, as the deep blue variety from Sri Lanka in which 'the colours of the rainbow sparkle'.

Jīmutaprabha is probably cloudstone or faint bluish marble. Moonstone or *candrakānta*, an intergrowth of orthoclase and albite, with pearly opalescent reflection, blue bloom and lovely sheen (available in Sri Lanka), was probably meant in the *Arthaśāstra's nandaka* (2.11.31) and *śītavṛṣṭi* (2.11.32). *Sūryakānta*, classified with *sphaṭika* or quartz (2.11.32), is clearly sunstone, which is sodium-calcium feldspar with strong optical interference, reflectivity and play of colour. Was Lord Kṛṣṇa's famous *syamantaka* a sample of *sūryakānta* or *vajra* (diamond)?

The *Arthaśāstra* also mentioned several subsidiary types of gems named after colour, lustre or place of origin (2.11.35):

> *Vimalaka*, white-red, *jyotirasaka*, white-red (could be agate and carnelian; *vimalaka* could also be shining pyrite), *lohitākṣa*, black in the centre and red at the fringe (magnetite; and hematite on the fringe?), *sasyaka* blue copper sulphate, *ahicchatraka* from Ahicchatra, *śukticūrṇaka* powdered or small oyster, *kṣīravaka*, milk coloured gem or *laśuna* and *śukla pulaka* (with horripilation or chatoyancy) which could be cat's eye variety of chrysoberyl, and so on.

At the end was mentioned *kācamaṇi*, the amorphous gems or artificial gems imitated by colouring glass (2.11.36). The technique of *maṇirāga* or imparting of colour to produce artifical gems was specifically mentioned (1.18.8; 2.12.1). The Indians were experts in producing artificial gems like beryl, ruby, sapphire, etc., and this has been attested by the Greek and Roman travellers and recorded in Sanskrit literature like the famous play *Mṛcchakaṭika*.

Non-gem Minerals and Materials

The *Arthaśāstra* mentioned the uses of several non-gem mineral and materials such as pigments, mordants, abrasives, materials producing alkali, salts, bitumen, charcoal, husk, an agricultural waste, etc.

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In use as pigments were *añjana*, antimony sulphide (2.11.35; 2.12.6 & 24) *manaḥśilā,* red arsenic sulphide (2.12.2; 2.14.48 etc.), *haritāla*, yellow arsenic sulphide (2.14.48; 2.22.6) and *hiṅguluka,* mercuric sulphide (2.13.19 & 46 etc.). These were also used as alloying reagents. Another pigment *gāndhāra* red lead (2.14.35) was used like *hiṅguluka* for embedding gold on metals. *Kāsīsa* green iron sulphate (2.13.19) and *sasyaka*, blue copper sulphate (2.11.35; 2.12.6) were used for colouring agents and later as mordants in dyeing clothes. Corundum or *kuruvinda*, having hardness nine in Moh's Scale, was appropriately used as an abrasive (2.14.48) like diamond powder.

Conch-shells (2.6.4; 7.12.24) and oyster-shells (2.11.35) were used not only for making bangles and other decorative items, but also to prepare *kṣāra* or alkali by calcination of calcium carbonate contained in it to alkaline calcium hydroxide (2.12.27). The word *kṣāra* meant 'an extract' and denoted sugar (2.15.14) as well as alkali from calcareous materials (2.12.27) and from the ash of barley *yavakṣāra* (2.12.9; 2.15.15) or *māṣa*-bean, sesamum, *palāśa*, etc. (2.12.9).

Yavakṣāra or barley ash (containing potassium carbonate etc.) was considered to be one of the 'salts' or *lavaṇas*. The group of salts or *lavaṇavarga* included salt from saline soil, from the sea, *biḍa* salt which contains apart from sodium chloride, some calcium and magnesium salts and red iron oxide, pit salt and *sauvarcala* or borax (2.15.15).

Śilājatu (2.12.4) or bitumen, also known as *adrija* was used as a medicine since the Harappan times and also a coating agent. Charcoal and husks from the forests and agricultural fields were utilised for their calorific value and carbonaceous content, in metal workshops, and the resultant ash further utilised for plastering walls (2.15.60 also 2.17.16).

Of great commercial importance were metallic ores from which useful metals were extracted. The *Arthaśāstra* did not provide the names of the constituent minerals beyond referring to them as *dhātu* of iron (*tīkṣṇadhātu*), copper, lead, etc.

Metallic Ores

The *Arthaśāstra* is the earliest Indian text dealing with the mineralogical characteristics of metallic ores and other mineral-aggregate rocks. It recognised ores in the earth, in rocks, or in liquid form, with excessive colour, heaviness and often strong smell and taste (2.12.1).

The text described a 'liquid ore' which seems to be a petroleum like bio-geo-

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genetic material. This liquid 'flows inside a hole, a cave, a table-land, dug-out mountain whose regions are known to contain gold ore'. This liquid is coloured yellow, viscous, clear and heavy and thrown in water, spreads on the surface like oil' (2.12.2-3). The description agrees to that of petroleum of asphalt basis as found in the Punjab and Baluchistan. (Roy, 1946:113) A very similar material with stronger small and taste was known to be bitumen or *śilājatu* (2.12.4). These materials were erroneously believed to contain gold and mentioned as 'metallic ores' or *dhātu*.

The *Arthsaśāstra* described a gold-bearing ore which Roy (1946: 113-14) has interpreted as typical auriferous pyrite. We reproduce the translation of the relevant section (2.12.5) of the *Arthaśāstra* with Roy's interpretation in the parentheses:

> Those ores which are obtained from the planes, or slopes of mountains; which are either yellow (pyrite is yellow), or red as copper, or reddish yellow (pyrite often becomes pseudomorphous after limonite and then develops brown colour) which are disjoined (individual crystals of pyrite), and marked with blue lines (grain boundary of chalcopyrite and pyrite) . . . . which are marked with spots like drops of curd (quartz is the curd-white mineral), dazzlingly bright yellow as turmeric (native gold), when broken, show lines, spots or *svastikas* of fine sand (minute crystals of pyrite occur between larger crystals; when isolated, such layers readily crumble away and become like sand grains; separation of metallic gold in the form of rings has been reported — the *svastika* represents the skeleton of a gold crystal separated out of gradually decomposing auriferous pyrite); which contain globular masses (decomposed pyrite showing iron hat); and when roasted, do not split but emit foam and smoke (i.e., sulphur dioxide gas).

Similarly, the silver ore described in the *Arthaśāstra* (2.12.6) seems to be a complex sulphide ore containing silver: "colour of a conch-shell, camphor, *vimalaka* (pyrite?) *sasyaka* (copper sulphate, an oxidation product of associated copper sulphide), containing lead (galena), *añjana* or antimony (as sulphide), smells like raw meat (smell of sulphur), ores which are disjoined (cube-shaped particles of cleaved galena), grey or blackish white (colours of galena, argentite or tetrahedrite); when roasted do not split, but emit much foam and smoke (galena and argentite evolve SO_2 gas, and galena forms white incrustation of lead oxide or charcoal)".

The *Arthaśāstra* described the sources and the qualities of good grade gold

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and silver ores (2.13.3-5 & 10-12). The quality had to be tested through streak on suitable stone-plate (2.13.17-27).

Copper ores were stated (2.12.12) to be 'heavy, greasy, tawny (chalcopyrite left exposed to air, tarnishes), green (colour of malachite), dark blue with yellowish tint (azurite), pale red or red (native copper)'. Lead ores were stated to be (2.12.13) grayish black, like *kākamecaka* (this is the colour of galena), yellow like pigeon bile (lead ore gossan), marked with white lines (quartz or calcite gangue minerals) and smelling like raw flesh (odour of sulphur). Tin ores could be (2.12.14) grey like saline earth (witherite?) or brown like burnt earth (cassiterite). Iron ore was known (2.12.15) to be greasy stone, pale red colour (orange limonite) or of the colour of the *sinduvāra* flower (hematite). Lahiri (1968, 1971) commented that 'the rock with greasy feel seems to be phyllite, and that with the pale red colour, jasper'. This matches with the characteristic of the bedded iron ores of Bihar and Orissa.

After describing the above metallic ores or *dhātus* of specific metals, the *Arthaśāstra* writes :

> काकान्ड भुजपत्रवर्णो वा वैकृन्तकधातुः
>
> *kākānḍa bhujapatravarṇo vā vaikṛntakadhātuḥ*
>
> (2.12.16)
>
> That which is of the colour of *kākānḍa* (crow's egg) or birch-leaf is *vaikṛntaka* ore.

This presumably refers to the ore of *vaikṛntaka* (mentioned as a metal in 2.12.23; 2.17.14 and 4.1.35), the identity of which is not known. Roy (1946:113) suggested that since magnetite is black and becomes brown on surface oxidation being changed to hematite, *vaikṛntaka* ore is magnetite. In that case *vaikṛntaka* metal must be iron itself which used to be produced by the South Indians starting from the magnetite ore. It was later known as *kāntaloha*.

Kangle (1986: Part II, p. 108 footnote) however quotes a view that *vaikṛntaka* could be an alloy or metal made in China. This could be nickel metal or nickel alloy. It may be recalled that during the third to first century BC, the Chinese copper-nickel alloy was used in Taxilā and north-west India for coinage, jewellery and fancy goods. This was known as *pai-t'ung* or *tutenag(ue)* or white copper. It is not certain whether *vaikṛntaka* metal was nickel or magnetite-based iron.

Apart from colour or external appearance, another important property of ore was known to be its density or heaviness, a variable property reflecting the metal content :

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सर्व धातुनां गौरववृद्धौ सत्ववृद्धिः
sarva dhātunāṃ gauravavṛddhau satvavṛddhiḥ
(2.12.7)

In the case of all ores, when there is increase in heaviness, there is increase in metal-content.

This phenomenon is due to the fact that in most cases, the metal-bearing minerals are heavier than the associated gangue minerals.

Precious Metals: Gold, Silver and their Alloys

The *Arthaśāstra* mentioned specific uses of various metals of which gold and silver received maximum attention.

The duties of *suvarṇādhyakṣah*, the Superintendent of Gold were defined in section 2.13. He was supposed to establish industrial outfits and employ *sauvarṇikas* or goldsmiths, well-versed in the knowledge of not only gold and silver, but also of the alloying elements such as copper and iron and of gems which had to be set in the gold and silver wares (2.13.1-2 & 58-59). The Superintendent had to arrange security preventing smuggling, theft (2.13.30-36) and pilferage by the artisans. Various possible methods of pilferage were described (2.14.18-55).

The purity of the raw-materials — gold and silver ore, scrap and ornaments for re-use — had to be checked through streak tests on special touchstones (2.13.17-25) and chemical tests such as whitening of gold by vermilion or iron sulphate (2.13.19).

Gold-smelting was known as *suvarṇapāka* (1.18.8). Gold was purified by a process of extraction with molten lead. Gold thus produced was brittle and had to be re-smelted. Thereafter, it was turned into leaves by heating, and made bright with Indus-earth when it became the base of various colours to be imparted through alloying with silver, copper, iron, etc. (2.13.6-9 & 47). Similarly, silver could also be purified using molten lead and then used as such (pure silver suitable for ornament is *tāra*) or alloyed to produce different colours (2.13.10-14 & 49).

Various ornamental alloys could be prepared by mixing variable proportions of iron and copper with gold, silver and *śveta tāra* or white silver which contained gold, silver and some colouring matter (2.13.50-57). Two parts of silver and one part of copper constituted *triputaka*. An alloy of equal parts of silver and iron was known as *vellaka* (2.14.20-22).

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The range of a goldsmith's expertise lay in setting, stringing, bead-making, making of solid and hollow objects, plating, coating, fixing and gilding (2.13.37-46; 2.14.17). *ghanaṃ suṣiraṃ saṃyuhyam avalepyaṃ saṃghātyaṃ vāsitakaṃ ca kārukarma* (2.14.17). The main products were *kāncana pṛṣata tvaṣṭṛ tapanīya* (2.13.33) gems set on silver and gold, beads, gold-plates and gold/silver ornaments. Setting is the fixing of gems (*kṣepaṇaḥ kācārpaṇādi* (2.13.38) on gold and silver base. Stringing is weaving in threads (2.13.39). Gold plating (*tvaṣṭṛkarma*) could be done on silver or copper (2.13.44-45). Gilding a silver article was done by means of the liquid or powder of sand vermilion (2.13.46).

A firm and a removable enclosing (*peṭaka*) was made in cases of plating, coating and fixing. Lead, copper or silver objects were coated with a gold-leaf (*ācitakapatra*) on one side or with a twin-leaf fixed with lac etc. (2.14.26-33). Gold, silver or gems were embedded (*pinka*) in solid or hollow articles by pasting a thick pulp (of gold, silver or gem particles and the cementing agents such as lac, vermilion, red lead) on the object and then heating (2.14.34-42).

The qualities of 'excellent ornaments' were defined (2.13.60-61), and the goldsmiths had to make them according to the specifications, and incurring minimum losses in metals and gems, not exceeding the prescribed limits (2.14.2-10).

Minting Coins

The *Arthaśāstra* described a system of coinage based on silver and copper. One silver *paṇa* had a specific weight *karṣa* or *suvarṇa* equalling 16 *māṣakas*; its composition was one *māṣaka* of hardening alloy (iron, tin, lead or antimony), 4 of copper and the rest or 11 of silver. Half-, quarter- and one-eighth *paṇa* coins had proportionally smaller weights but the same alloy composition as that of a *paṇa*. The weight of one *māṣaka* copper coin was probably the same as that of a silver *paṇa*. The *māṣaka,* half *māṣaka*, quarter *māṣaka* known as the *kākaṇī*, and half *kākaṇī* copper coins (progressively lower weights) had the same composition, viz., one-quarter hardening alloy and the rest copper (2.12.24).

The Mint Master or *lakṣaṇādhyakṣaḥ* was supposed to supervise minting (2.12.24). *Lakṣaṇa* in this name refers to the emblem of the state stamped on the punch-marked coins. The use of the word *biṁba* or die (4.4.20) suggests that the coins were punch-marked and not cast. Businessmen could have their coins made, but only under supervision in the mint owned by the state. The Examiner of coins or *rūpadarśakaḥ* was authorised to monitor the production, purchase, sell and proper currency (*paṇayātrā*) or circulation of the coins (2.12.25-26; 4.1.44).

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The *Lohādhyakṣa*

The *Arthaśāstra* specified that the Director of Metals (*lohādhyakṣa*) should establish factories for metals (other than gold and silver) viz., copper, lead, tin, *vaikṛntaka* (?), *ārakūṭa* or brass, *vṛtta* (steel?), *kaṁsa* (bronze), *tāla* (bell-metal) and *loha* (iron or simply metal?), and the corresponding metal-wares (2.12.23). Some comments on these names are called for.

In the Vedic era, copper was known as *lohāyasa* or red metal. In the post-Pāṇini era, the nomenclature changed to *tāmra* and *śulva*. The element sulphur *gandhaka* was reckoned as *śulva-ari* (that which attacks *śulva* or copper) or *śulvāri* which was converted to 'sulphur' in the Western Indo-European languages. Copper used to be alloyed with arsenic to produce *tāla* or bell-metal and with *trapu* or tin to produce *kaṁsa* or bronze. It may be noted that tin had always been known in India as *trapu*. The other name *kastīra* came into vogue later during the Greek influence in India; *kastīra* was possibly derived from the Greek word *cassiterite* (tin ore).

Another Greek word *oreichalcos*, denoting brass or the copper-zinc alloy, was probably converted to *ārakūṭa* during the time of Kauṭilya. Although some copper artefacts, discovered in the archaeological sites of Lothal and Atrañjīkherā (2000 and 1000 BC respective dates), contained zinc, the actual manufacture of zinc in India must have strated around 400 BC in Taxilā. The *Arthaśāstra's* references to *ārakūṭa* (2.12.23; 2.17.14; 4.1.35) and to red lead *gāndhāra* (2.14.35), a product from Gāndhāra, testify the author's familiarity with the North-West India of the period fourth century before Christ. The author was most likely Cāṇakya or Viṣṇugupta himself.

On *Vaikṛntaka*, *Vṛtta* and *Tīkṣṇa*

We have already discussed the unsolved puzzle regarding the identity of *vaikṛntaka*. All we know is that it was a metal or alloy prepared from its ore or *dhātu* (2.12.16) which, according to Roy (1946:113), could be magnetite. *Vaikṛntaka* has been referred some times (2.12.23; 4.1.35 etc.) with *vṛtta*, which is identified by many scholars including Kangle, as steel. In one place (2.17.14), *vaikṛntaka* and *vṛtta* have been mentioned with *kālāyasa*, which is evidently the Vedic name for pig or wrought iron; thus, the three (in 2.17.14) were presumably believed to be different from each other. On the top of it, *tīkṣṇa* mentioned as iron, had its ore or *dhātu* (2.12.15), and the metal was used as an alloying component (2.12.24; 2.13.48 & 58).

We propose that *kālāyasa* stood for pig or wrought iron and *tīkṣṇa* was carburised iron (not cast iron) which gave sharp (*tīkṣṇa*) tools. *Tīkṣṇadhātu* was

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possibly hematite. Iron prepared from South Indian magnetite or *vaikṛntakadhātu* was wrongly believed to be a different metal *vaikṛntaka*. *Vṛtta* was most possibly steel or carburised iron prepared in crucible; this cementation product was later known in South India as *wootz*. The name *vṛtta* arose possible in view of the approximately **circular** cross-section of the steel ingot solidifying in the crucible. About 108 such ingots, each approximately 1-2 inch in cross-section, 5-6 inch in length and 3-4 lbs. in weight, were obtained in the first century AD stratum of the Sirkap mound at Taxilā. These specimens were not tempered like steel but assayed high (1.2-1.7) p.c. in carbon.

Iron and Steel Armoury

A bar and a broken sword of steel were found at the bottom of the Khan Baba stone Pillar of Heliodorus (dated before 125 BC). The sword assayed 0.7 p.c. carbon and was certified by Sir Robert Hadfield as having been 'deliberately manufactured as steel' (*Archaeological Survey Report*, 1913-14, pp. 203-4). This discovery lends credence to the *Arthaśāstra* mentioning *vṛtta* (steel) and various war equipments such as *khaḍga* (sword). M. Rostovtzeff (1941) was of the opinion that the best kind of steel was Indian in origin; gradually the technology was adopted in Persia and Asia Minor, and in the post-Christian era, Indian *wootz* was imported to Syria to produce the famous sword of Damascus and the damascene steel.

The *Arthaśāstra* outlined the duties of the Superintendent of the *āyudhāgāra* or Armoury; he should supervise making of weapons, armours and accoutrements by artisans, and also of machines for use in battles, for the defence of forts and for assault on the enemies' cities (2.18.1). Various kinds of iron or steel swords were described: *nistriṁśa* (with curved tip and beyond thirty *aṅgulas*), *maṇḍalāgra* (straight with a round tip), *asiyaṣṭi* (thin and long), each variety provided with hilts made of horn of the rhinoceros or buffalo (2.18.12-13). The razor-type (*kṣurakalpāḥ*) weapons were: *paraśu* (all metal 24 *aṅgulas* long), *paṭṭasa* (an axe with a trident at one end or both ends), *kuṭhāra*, *khanitra*, spade, *trakaca* or saw, *kāṇḍacchedana*, a big axe, etc. (2.18.14). Various shields and armours like *lohajālikā, paṭṭa, kavaca*, etc. were manufactured (2.18.16). Arrows were iron-tipped (2.18.11). The fixed and mobile 'machines' were used to hurl metallic and stone missiles (2.18.5-6).

Since casting of iron needed high temperature, and was not invented in ancient India, big objects of iron were usually made by hot forging of smaller pieces (7.3.8-9) of ingot such as those described earlier:

तेजो हि संधानकारणं, नातप्तं लोहं लोहेन संधत्त।

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tejo hi saṃdhānakāraṇaṃ, nātaptaṃ lohaṃ lohena saṃdhatta ।

Various equipments for mineral and agricultural processing such as implements for weighing and measuring, grinding stones, pestle and mortar, pounding and crushing machines, scatterer, winnowing basket, sieve, etc. (2.15.62), and blacksmithy equipments such as bellow, pincer, vice, anvil, dies, chisels and crucibles (4.4.20) were mentioned in the *Arthaśāstra*.

Tulā māna deśa kāla Pautavam

There were strong resemblances between the phenomena of the first urbanisation in India (Harappan civilization) and the second, in the *mahājanapadas* of the first millennium BC. The second phase witnessed a revival of not only the widespread used of minerals and metals, and extensive trade, but also of the necessary infrastructure for scientific standardisation of commodities and parameters. The *Arthaśāstra* prescribed standardisation (*pautava*, from the word *pu*, to purify, refine) of weights (*tulā*) and measures (*māna*), space (*deśa*) and time (*kāla*) (sections 2.19 and 2.20). A superintendent (*pautavādhyakṣa*) was supposed to supervise the manufacture and proper use of standard weights and measures (2.19.1).

Standard weights were made of iron or metallic stone from Magadha or Mekala hills which would not be affected by heat or water (2.19.10). Ten *māṣa*-beans were taken as equivalent in weight to one *māṣaka* of gold, which was one-sixteenth of one *suvarṇa* or *karṣa* (2.19.2-3). Eighty-eight white mustard seeds make one *māṣaka* of silver which is two-fifth of gold *māṣaka*. Manu (8.134-135) gives the same ratio between the gold and the silver *māṣakas*. A *pala* is equivalent to four *karṣas* and ten *dharaṇas*. A *dharaṇa* of diamond weighs twenty rice-grains (2.19.2-7).

Similarly, length, area and volume or space (*deśa*) were standardised (2.20. 1-27). Time (*kāla*) was standardised in terms of the solar shadow (of the gnomon), and for the night and a cloudy day, by the water-clock or *nālikā* (1.7.8; 1.19.6). A *nālikā* was defined as the time taken for one *ādhaka* of water in a jar to flow through a hole of diameter equalling that of a four *māsaka* weight gold wire having a length of four *aṅgulas* (2.20.35).

Conclusion

It is thus established that *Kauṭilīya Arthaśāstra* records Indians' skill in processing gem minerals, metallic ores, metals, alloys and the end-products as well as an aptitude for scientific methodology during the sub-continent's early Historical Period.

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The references to the South Indian gems and red corals from the West have induced some scholars to suggest that the *Arthaśāstra* was compiled in the post-Christian era after the Indo-Roman trade on precious gems and metals had begun. This view is unacceptable since it is well recorded that centuries before Indo-Roman trade contact, King Aśoka had cultural and trade contacts with Sri Lanka, Persia, Syria etc.

As a matter of fact, the Indian vessels were coasting along Gedrosia to Arabia and the Persian Gulf before the time of Alexander, for Nearchus got a guide in Gedrosia who knew the coast as far as the Gulf of Ormuz. (Tarn, 1938) The *Arthaśāstra* mentions (4.3.12 & 15) the voyage of Indian vessels from the Mahākaccha, and contains no reference to Rome or the Roman vessels. Indian army equipped with iron-tipped arrow and iron swords assisted Xerexes and other Aechemenid emperors in fighting Greece. Alexander's historians testified to the gorgeous ornaments used by the Indian kings. These were fifth and fourth century BC events, (long before the Romans came to India), and therefore, placing the *Kauṭilīya Arthaśāstra* in the later half of the fourth century BC is entirely in order; this view has been elaborately justified in the beginning of this chapter.

The *Arthaśāstra* has been criticized for recommending strong-arm tactics and even cruelty, but no state, ancient or modern, has ever discarded these administrative techniques. This text does accept non-violence and moderation as the highest principles (1.3.13), but does not abjure violence as a means to counter internal dissension and external aggression. Mineral, metal and other resources had to fill the treasury and nourish the army, which in its turn had to serve the stark realities of the state politics and national integrity.

Most scholars have missed a cardinal point about the *Arthaśāstra*. Although the text deals with technology, economics and politics, and accepts the Vedic religion, it does not subscribe to the views (1.2.2-7) that any one of the above subjects should occupy supreme position in human society. Kauṭilya gave maximum importance to *Ānvīkṣikī*, which may be translated as philosophy of critical investigation based upon reasoning, and which constituted of *Sāṁkhya*, *Yoga* and *Lokāyata* (all these were non-Vedic) philosophical systems. *Ānvīkṣikī* was supposed to bring out the merits as well as the fallacies of economics, politics and also the Vedic religion :

> Investigating, by means of reasoning (*hetubhiḥ anvīkṣamāṇā*) what is spiritual good and evil in the three *Vedas* (*dharmādharmau trayyām*), gain and loss in economics (*arthānarthau vārttāyām*), good policy and bad policy in the science of politics, as well as the relative strength and weakness (*valāvale*) of these three sciences,

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philosophy confers benefit on the people, keeps the mind steady in adversity and in prosperity and brings about proficiency in thought, speech and action. (1.2.11)

Therefore it was concluded:

प्रदीप: सर्वविद्यानाम् उपाय: सर्वकर्मणाम्।
आश्रय: सर्वधर्माणाम् शश्वत् आन्वीक्षिकी मता।।

pradīpaḥ sarvavidyanām upāyaḥ sarvakarmaṇām ।
āśrayaḥ sarvadharmāṇām śaśvat ānvīkṣīkī matā ।।
(1.2.12)

(Critically investigating) philosophy is eternally thought of as the lamp of all sciences, as the means of all actions and as the support of all laws and duties.

Kauṭilya's scientific attitude shines brilliantly in his sharp criticism of the obsession for astrology:

नक्षत्रम् अति पृच्छन्तम् बालम् अर्थो अतिवर्तते।
अर्थो हि अर्थस्य नक्षत्रम् किम् करिष्यन्ति तारका:।।

nakṣatram ati pṛcchantam bālam artho ativarate ।
artho hi arthasya nakṣatram kim kariṣyanti tārakāḥ ।।
(9.4.26)

The object slips away from the foolish person, who continuously consults the stars; for an object is the (auspicious) constellation for (achieving) an object; what will the stars do?.

In the previous chapter, we referred to the sterling concepts of *pramāṇa*, *upajñā* and *upakrama* in Pāṇini's *Aṣṭādhyāyī*; Kauṭilya's supreme contribution in his *Arthaśāstra* was the concept of *ānvīkṣikī*. Indian science prospered in the subsequent centuries to the extent the above concepts were pursued. Later, the decline started when the caste-ridden society was affected with vainglory and superstition, and ignored the scientific concepts of Pāṇini and Kauṭilya.

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6

Minerals and Metals in the Indian Epics from An Archaeological Viewpoint

THE Indian epics, *Rāmāyaṇa* and *Mahābhārata*, constitute a part of the nation's sacred traditions respected by millions. On the other hand, the tradition of archaeology is to unveil truth and not to romanticize the cavalcade of myths. The Ayodhyā archaeology seems to start with the PGW culture, whereas the Hastināpur excavations show that its earlier OCP culture may be dated before 1200 BC. Thus, contary to the popular notion, the date of the story is earlier for the *Mahābhārata*, to which most of our remarks would be confined. We would briefly mention the *Rāmāyaṇa* and the Buddhist literatures towards the end.

The Antiquity of the Background of the Epic Story

The *Mahābhārata* clearly recalls the earlier Ṛgvedic civilization on the shores of the *Vinaśana*, the lost river Sarasvatī. The archaeological findings in this area point out settlements in the third and second millennium BC. The Pre-Harappan Sothi culture in Kālibaṅgan was followed by the urban Harappan settlements in Kālībaṅgan, Banawālī, etc. Bhagwānpura (Kurukṣetra district), Dadheri (Ludhiana), Katpalon and Nagar (Jullundur) are credited with the interlocking of the PGW and the Harappan material. (Sharma, 1983:23-24 and 172-73) They exhibit the once forgotten, but newly discovered link between India's first urban culture (Harappan) and the second (Historical period).

Thermoluminescence dating by BARC, Bombay, has established that the settlement at Bhagwānpura started around 3000 BC and the change-over to the PGW culture took place around 1220 BC (Joshi and Madhubala, 1982: 193-94); this transition occurred between the sixth and seventh layers in the site. The

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onset of the PGW culture at the *Mahābhārata* site of Hastināpura, and also at Atrañjīkherā, took place around 1100 BC; in these sites the earlier cultures thrived on OCP wares. At Bhagwānpura, the excavations yielded terracotta ear ornaments, bangles of copper, shell, faience and glass, *ghaṭa*-shaped beads, semi-precious stone beads, bone and ivory hair-pins, violin-shaped Mother Goddess (Sarasvatī?) statues, wheeled terracotta rams (*vāhana* of Sarasvatī?). Oval structures made of baked bricks found at Bhagwānpura, Dadheri, Nagar and Katpalon most possibly had religious affiliations. (Joshi, 1987: 19-23) This region of the Sarasvatī Valley was considered to be holy in the later age of the epics, and quite significantly we find the principal characters of the epics, such as Balarāma in *Mahābhārata*, undertaking elaborate pilgrimage tours in the area.

Apart from Hastināpur and Ahicchatra, the *Mahābhārata* story also refers to Indraprastha (modern Delhi) and Dwārkā as important sites. For obvious reasons detailed excavations could not be undertaken in the city of Delhi. However the recent marine archaeological excavation of the submerged port of Dwārkā has yielded important evidences and a significant date. (Rao, 1988: 47-53)

Off the shore of the modern Dwārkā, lies the ruin of the mid-second millennium BC port of Dvārakā or Dvārāvatī, founded by Lord Kṛṣṇa. Underwater expedition has shown fortification wall of limestone blocks and stones measuring around 2 × 1 × 0.5 m sizes. Some moonstone pieces recovered from the debris suggest that a religious structure existed there. The retrieved chert blades and sherds of lustrous redware and black- and redware are clearly of the Late-Harappan origin; the triangular and prismatic shaped stone anchors having three holes each are analogous to the anchors used in the fourteenth century BC Syria and Cyprus. A small seal of conch-shell has an animal motif, reminiscent of the Bahrainian art. A jar bears an inscription in the Late-Harappan characters (partly resembling Semitic and partly Brāhmī) which has been deciphered by Rao (1988:52) as *mahahagacha Shah Pa* conveying the sense 'Sea Lord Protect'. Rao had earlier (1982) deciphered the Indus Valley Script and showed how this script was eventually transformed into the Late-Harappan and the Brāhmī.

To cap it all, A.K. Singhvi of PRL, Ahmedabad announced that the pottery sample no. 9 from the rubble wall in cliff section of BDK I (Period I) in the underwater Bet Dwarka had been thermoluminiscence dated as 3520 BP or 1533 BC. (Rao, 1988: xxiv and 52) Some scholars have adduced reasons to propose that the *Mahābhārata* war took place around 1465 to 1430 BC.

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The Text of *Mahābhārata* in the Light of the Archaeological Evidences

The date of the *Mahābhārata* war has been variously suggested as 3100 BC, 1900 BC, 1400 BC and 900 BC. While we tend to favour the last two dates 1400-900 BC, we also agree with Joshi (1987:20) that the kind of war that was described in the epic, with the full range of iron weapons, could not have been fought before 600 BC. Inevitably, the conclusion, as drawn by Lad (1983), emerges that there was a core of the story existing before 800 BC, essentially as a folklore and orally transmitted, which became heavily padded with the later-day experiences. Additions to the text were made in several instalments during 500-100 BC, 100 BC - AD 100 and AD 100-400. Thus, instead of discussing minerals and metals mentioned in the epic *Mahābhārata* as a coherent subject or referring to them as the material resources in India during any particular epoch, we should rather follow Lad (1983:66) in relating the specific references to minerals and metals with the different era during which such references were introduced in the text as additional extravaganza and distortions.

Lad (1983: 66-68) pointed out several reasons to believe in the antiquity of the epic. Some of the heroes of the epic such as Vāsudeva Kṛṣṇa, Arjuna, etc. have been mentioned in the *Chāndogya Upaniṣad* (3.17.6) and *Aṣṭādhyāyī* of Pāṇini (4.3.98) which correspond to the eighth century and sixth-fifth century BC period respectively. *Āsvalāyana Gṛhya Sūtra* (3.4.4) eulogized the epic and *Sāṅkhāyana Śrauta Sūtra* (15.16) referred to the Kurukṣetra war. These *Sūtras* may be dated around sixth century BC. Kauṭilya and Patañjali have also referred to the epic. It is quite possible therefore that a small core of the epic was in circulation before the eighth century BC.

An early version of the epic probably referred to the pastoral economy and unsophisticated agro-rural set up as in vogue in Bhagwānpura and Hastināpura during the OCP and early PGW era. As a matter of fact, several archaic features, not only of language and construction, but also of culture contained in the epic 'have managed to escape the scrubbing and polishing of later centuries'. Some of the awkward and conspicuous examples have been cited by Lad (1983:66).

The food habits of some of the princely heroes are almost primitive: they cook their own meat-broths. They dress simply in cotton cloth and hardly wear decorative shoes. Sugar, quite common in India by 400 BC, is nowhere on the scene in the epic. The complete absence of coins and money economy (*niṣka* is more of a gold ornament than a piece of coin) proves the distant origins of the epic. Conch-shell bangles were of Harappan tradition and pearls were mentioned in the *Vedas*. Glass (*kāca*) and quartz crystal (*kācamaṇi*) were rarely mentioned.

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Although Ahicchatra and Girivraja (modern Rājgīr) occur in the epic, Pāṭaliputra founded in the sixth century BC is not mentioned, proving the antiquity of the epic. At several places in the epic, the modest descriptions fit in with the early PGW cultures in Hastināpur etc., which were hardly urban, and were at best large agro-rural settlements resembling that in the Late-Harappan Bhagwānpura. (Ghosh, 1973: 9-11; Sharma, 1983:172-73 and Joshi 1987: 27)

500-100 BC Additions

The first major portion of additions and accretions came during the Historical Period. The large number of gems, ornaments, iron weapons, and metal utensils mentioned in the *Mahābhārata* have their exact counterparts in the Buddhist Pāli literature. The materials were either processed in North India or brought from South India or across the Western frontiers under the influence of the Persians and Greeks, and later Scythians and Romans.

References to *vaidūrya* or beryl (1.143.23; 2.48.30; 3.39.17; 4.36.39, etc.) clearly show that this part of *Mahābhārata* was composed after fifth century BC. The Vedic literatures do not mention beryl, and the first time this is introduced in the Sanskrit literature is by Pāṇini. The epic *Mahābhārata* itself refers to the South Indian topography which yielded beryl and other gems during the Historical Period :

प्रागायता महाराज षड़ेते रत्नपर्वता:
अवगाढ़ा हि अभयत: समुद्रौ पूर्वपश्चिमौ
नीलश्च वैदूर्यमय श्वेतश्च रजतप्रभ:
सर्वधातुविनद्रूश्च श्रृंगवान्नाम पर्वत:
prāgāyatā mahārāja sadete ratnaparvatāh
avagāḍhā hi abhayataḥ samudrau pūrvapaścimau
nīlaśca vaidūryamaya śvetaśca rajataprabhaḥ
sarvadhātuvinadrūśca śṛngavānnām parvataḥ
(6.7.2-3)

Mount Nīla (Nilagiri) probably derived its name from the sea-blue aquamarine in the Coimbatore district. The ocean and Sri Lanka have been mentioned as the chief sources of gems such as beryl, pearl and coral etc:

समुद्रसारं वैदूर्य मुक्ता: शंखान् तथैव च
शतशस्च कुथां स्तत्र सिंहला: समुपाहरन्
samudrasāraṃ vaidūrya muktāh śaṅkhān tathaiva ca
śataśasca kuthām statra simhalāh samupāharan
(2.48.30)

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The international trading port Barygaza in Gujarat or modern Broach was known as Bhṛgukaccha or Bharukaccha. Its importance was acknowledged:

भरुकच्छं गतो धीमान् दूतान् माद्रवतीसूतः
bharukacchaṃ gato dhīmān dūtān mādravatīsūtaḥ
(2.28.50)

Mention was made of *bharukacchanivāsinaḥ* (2.47.8).

Green beryl (*vaidūrya*) has been clearly distinguished from sea-blue aquamarine (*nīla vaidūrya*):

Vaidūryaharitānīva (5.98.10), *nadīśca bahulāvartā nīlavaidūrya sannibhāḥ* (3.39.17), *nīla vaidūrya sadṛśa indanīlanibhaḥ kvacit* (12.326.5). Further distinction has been made from *nīlāñjana* (12.326.3) or carrollite and *indranīla* (12.326.5) or sapphire.

Emerald is the deep green variety of beryl. This gem was not available in the South, and it is doubtful whether the Udaipur, Rajasthan reserve was tapped that early. Most probably the supply of emerald came from the Asiatic side of the Ural mountains, 80 km east of Sverdlosk, or from Ethiopia or Egypt. At any rate, according to Pliny and the *Periplus*, Rome received emerald at one stage through India alone; this trade was possible only during the Christian era. The *Mahābhārata* refers to emerald, *marakata* or *masāra* in several places:

पित्तान् मरकतं यथा
pittān marakataṃ yathā
(3.213.13)

मसारगल्वर्कमयैः विभंगैः भूषितम् हेमपिनद्रू चक्रम्
masāragalvarkamayaiḥ vibhangaiḥ bhūṣitam hemapinadrū cakram
(12.46.33)

Amongst the beryl-like green gems, the light green beryl was the most popular one in ancient India. The *Mahābhārata* provides evidences as to how popular beryl had become to the Indians. The sparkling green of flowers (2.155.61), petals (12.95.15), fresh moss (1.143.23), young shoots of grass (5.118.8) etc. were compared with the beautiful green *vaidūrya*:

नदीद्वीप प्रदेशेषु वैदूर्य सिकतासु च
nadīdvīpa pradeśeṣu vaidūrya sikatāsu ca
(1.143.23)

वैदूर्यांकुर कल्पानि मृदुनि हरितानि च
vaidūryānkur kalpāni mṛduni haritāni ca
(5.118.8)

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वैदूर्यपत्र विततां मणिनालमया अम्बुजाम्

vaidūryapatra vitatāṃ maṇināmayā ambujām

(2.3.27)

The earliest archaeologically recovered sample of beryl was from Bhir Mound III of Taxilā (fifth-fourth century BC). Beryl beads were also obtained from Kauśāmbī (150 BC) and Sirkap III (AD 100).

Vidruma or *pravāla* (coral) mentioned in the *Mahābhārata* (1.105.17, 3.212.13-14, 7.73.25, 12.326.3-5) also came from Sri Lanka and the Malabar coast and later from the Mediterranean Sea. Of course coral was known in the Chalcolithic India, and archaeological samples have been obtained in the successive periods of Prakash (Period I 1700-1300 BC, II 600-100 BC, III AD 100-300) Navdatoli (Period I 1600-1300 BC, III AD 100-300), Maski (Period I 900-400 BC, III AD 50-300). The most substantial finds however are from the Indo-Greek (Bhir Mound II Mauryan) and Indo-Roman Trading Period (Nevasa V 50 BC-AD 200). Roman corals along with many other materials were imported and found in Nevasa V. Medicinal value of coral was testified by Caraka and Suśruta around the first century AD.

Pearls, *muktā* or *mauttika* (Pāli) also came from Sri Lanka (2.48.30) and Gulf of Mannar. In the Vedic literatures, peral was known as *kṛśan*. This was probably conch-pearl or the darker variety from the Persian Gulf or the black mis-shapen perals from the winnow oysters of the Saurashtra backwaters (Lad, 1983: 30). During the historical period, the much better species of oysters (*Pinetada Vulgaris*), flourishing in the Gulf of Mannar and noted for its beautiful silvery white colour, were exploited for the pearl trade. There are many references to pearls in the *Mahābhārata* (1.191.13; 7.73.25; 9.34.31; 9.61.32; 11.165.17 etc.) Pearl necklaces were quite common (3.108.9; 3.146.25). A delicate network of pearls known as *muktājāla* used to be hung from doorways (13.20.36-37) and pillars in an auditorium etc.

मुक्ताजाल परिक्षिप्तं वैदूर्यमणि भूषितम्
शतकुम्भमयं दिव्यं प्रेक्षागारम् उपागमत्

muktājāla parikṣiptaṃ vaidūryamaṇi bhūṣitam
śatakumbhamayaṃ divyaṃ prekṣāgāram upāgamat

(1.124.13)

Such lavish use of pearls was possible only during the Mauryan and Post-Mauryan era. The use of bangles made out of conch-shell or *kambu* was rooted in the Harappan and the Post-Harappan chalcolithic traditions. However, at the time when the epic was written, shell bangles were used by lower class people

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only (2.54.13, 4.10.15-19, 4.15.2). Evidently, the newer commodities such as the fragrant *candana*, *aguru* and sandalwood from the South, were more attractive.

Diamond or *vajra* was very popular for its brightness *vajrasārojjvalāni* (5.98.10), but we do not know how much earlier before the first century AD (when *Pannā* mine was exploited), the actual diamond-mining had started in India. Sapphire (blue *indranīla* 12.326.5) was obtained from the gem-beds of Sri Lanka which contained more sapphire-blue variety of corundum, and less of ruby-red variety of the same mineral.

Sunstone (*sūryakānta* or *arka*) and moonstone (*candrakānta*) both belong to the feldspar family. In the sunstone structure, embedded hematite or goethite crystals scatter an internal glow of yellowish or reddish beams, and thus the mineral exhibits self-luminescence. The reference 12.46.33 quoted earlier, describes the chariot of the Lord Kṛṣṇa bedecked with gold, emerald and *arka* or sunstone. Was Kṛṣṇa's *syamantaka* a piece of sunstone or diamond?

The moonstone is an intimate combination of orthoclase and albite in an arrangement of thin layers to which it owes its beautiful blue bloom and its lovely sheen. This mineral has been available in the Kangayam district of Tamil Nadu in South India and also in the famous gem-gravels around Ratnapura in the south-western Sri Lanka.

Quartz or rock crystal has been mentioned several times as *sphaṭika* in the *Mahābhārata* (2.3.16 & 27; 3.212.13-14; 12.326.3-5 etc.). Due to its resemblance with glass, which was used to imitate gems, it came to be known as *kācamaṇi*, and gradually got devalued as a common place material. The epic mentions few other minerals such as *nīlāñjana* (12.326.3) which is probably the blue pigment carrollite, *ásmasāra* (2.47.14) (was it iron or agate or amethyst?) which was used to make *bhāṇḍa* or containers.

Metals in the *Mahābhārata*

During the Pre-Mauryan era, the Greek authors such as Herodotus (3.102-105) first mentioned about the legend of ant-gold in India. In the *Mahābhārata* also, we find the same topic: *pipīlikaiḥ jātarūpam* (2.48.4). Megasthanes (Indica 32), Strabo (15.1.44), Pliny (6.22;11.35) repeated the story that ant-golds came from Kashmir, Tibet and the Dardic region.

The mystery was solved in the nineteenth century (Ball 1881). It was found that a tribe in the Himālayas used to dig out gold in the extreme winter to avoid the prying eyes of the robbers. The miners' black tents made of yak hair looked like hairy animals from some distance. The miners spread the myth that big gold-digging ants used to dig that gold.

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From the Vedic age, *niṣka* was known as a prominent gold ornament and sometimes as a decorative lump of gold. In the *Mahābhārata*, this has been mentioned as an ornament for both men and women (1.67.2; 7.19.35); a round piece of gold, tied at the neck in a string or chain (7.91.26), at times several such pieces strung into a necklet (7.138.17). Rarely *niṣka*, *śatamāna* and *sāna* were mentioned as coins or money-exchanging units. Gold vessels were frequently mentioned but these were probably too costly to be left behind and to be subsequently recovered as archaeological items. Silver pitchers — *kalaśa* (15.3.12) and *kuṁbha* (8.6.37) — were probably items imported through Graeco-Roman trade (2.34.4; 2.47.16). Bell metal and brass (*kāṁsya*) were used as milking and drinking vessels (2.45.26; 2.49.3; 15.34.13-14). Sometimes these were gilded with gold (4.63.47).

The *Mahābhārata* recorded the onset of iron age in India. Iron is everywhere on the scene, for arrows, spears and other weapons referred to as *ayas* (6.50.68; 9.14.3), *pāraśava* (6.76.36; 9.14.14), *adrisāramaya* (3.170.49), *aśmasāramaya* (8.66.58), *kārṣnāyasa* (7.28.4), etc. Thirty to forty different types of arrows were described. The Vedic *rsti* disappeared. The sword (2.47.1) (*asi*, *khaḍga*) assumed increasing importance but the literature described it as a defensive weapon compared to the arrows. Similarly body-armours like *kavaca* (5.150.81), *varma* (1.28.11; 3.24.3), *dehāvarana* (8.10.29), *śirastrāna* (6.31.54; 8.16.25) were used for protection. A typical weapon associated with *durga* or fort was *śataghnī* (1.199.32; 3.274.22; 7.108.40; 9.12.24) which was a huge structure, studded with spikes and provided with wheels or *cakras*; this was described by Kauṭilya.

Post-Christian Era Additions to the Epic

The art of gem-incrustation was earlier known but popularized later in India by the Indo-Scythians and Parthians at Taxilā around the first century AD. Significantly, Lad (1983: 51 and 70-71) opines that the fifty odd references to the jewelled artefacts were entered in the epic during or after the aforesaid date. Some of the references are listed below.

Eight *vaidūrya* stones encased in gold were offered by Prince Uttara to Arjuna (4.36.39). Lord Kṛṣṇa, always dressed in yellow, was likened to a *mani* encased in gold (5.92.52; 12.45.14)

अतसीपुष्प संकाशः पीतवासा जनार्दनः
व्यभ्राजत सभामध्ये हेम्नीवोपहितो मणिः
atasīpuṣpa saṃkāśaḥ pītavāsā janārdanaḥ
vyabhrājata sabhāmadhye hemnivopahito maṇiḥ
(5.92.52)

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King Drupada presented to the Pāṇḍavas vessels or *bhājanas* ornamented with beryl and diamond:

शयनासन यानानि विविधानि महान्ति च
वैदूर्यवज्रचित्राणि शतशो भाजनानि च
śayanāsana yānāni vividhāni mahānti ca
vaidūryavajracitrāṇi śataśo bhājanāni ca
(1.191.15)

A few gold *pātras* ear-marked as gifts for brāhmaṇas were likewise incrusted with *vajra* (12.165.14). Similar silver dishes with gem incrustations were introduced at Taxilā by the Greeks around AD 100 for the first time; these were known as *paterae*. The drinking horn or rhyton of the Graeco-Romans was also imitated. In one solitary instance, the *Mahābhārata* (8.6.37) describes some elephant-tusks and rhino and cattle-horns, ornamented with pearls and precious stones, which were used as water-sprinklers during the consecration of Karṇa as the commander of the Kauravas.

The references to the Chinese silk (2.47.22), Bharukaccha and Roma (Rome):

अन्ताखीं चैव रोमां च यवनानां पुरं . . . भरुकच्छं गतो
antākhiṃ caiva romāṃ ca yavanānāṃ puraṃ. . . .
bharukacchaṃ gato (2.28.49-50)

clearly prove that insertions were made in the epic long after the onset of the Christian era. The description of the gold-decorated ornametal armour-coats in the *Virāṭaparva* is very significant on account of their close affinity with Sassanian metal works of the fifth-sixth centuries AD (Lad, 1983).

On *Rāmāyaṇa*

The above discussion on the *Mahābhārata* clearly shows that its references to the minerals and metals and various products indicate that the text of the epic was continually expanded over the centuries. Some of the specific portions of the text can be identified with specific periods in the Indian history.

The *Rāmāyaṇa* contains a much shorter list of minerals and metals probably because this epic itself is much shorter, and has been spared from the later-day interpolations. Like the other epic, the *Rāmāyaṇa* also must have been compiled in the present form during the Historical period and contains the usual references to the widely used minerals and metals.

The *Sundara Kāṇḍa* of this epic refers to *vaidūrya* or beryl (3.9), *vajra*

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(diamond), *sphatika* (quartz), *muktā* or pearl (3.10), *indranīla*, *mahānīla* or sapphire (9.16), *vidruma* or coral (9.17), etc. The metals mentioned are: *ayasa* (2.40.23), *kālāyasa* or iron (5.41.12), *kāṁsya*, bell-metal or brass (3.29.20; 4.50.34), copper (4.23.20), lead and tin (1.37.20) etc.

Buddhist Literature Sources

The major portions of the two epics were compiled during the Maurya Period. During this era the Pāli canons were also recorded in writing. This fact is reflected in the similar references related to minerals and metals in India. Some specific points may however be noted.

The Buddhist literature mentioned seven kinds of jewels or *ratna*: *suvanna* (gold), *rajata* (silver), *muttā* (pearl), *veluriya* (beryl), *vajra* (diamond), *pravāla* (coral) and *maṇi* or miscellaneous gems (*Milinda*, Vol.1, p. 267, *Jātaka*, Vol. 6, p. 480). Different kinds of *lona* or *lavana* or salts mentioned are: *samuddalona*, *kālālona*, *saindhavalona*, *sovirka*, etc. *loṇakāras* used to process salts. Decorative pigments or *añjanas* were widely used. Five kinds were mentioned: *kālā*, *seta*, *rasa*, *geruka* and *kappila* (*Dīgha Nikāya*, Vol.1, pp.7, 12; *Jātaka*, Vol.1, p.194; Vol.2, p.369; Vol.5, p.416).

Aṅguttara Nikāya (Vol.3, p.116) recognised five kinds of metal or *jātarūpa*: *ayo* (iron), *loho* (copper), *tipu* (tin), *sisā* (lead) and *sajjha* (silver). Knife and needle (*sūci*) made of iron were mentioned. *Dhammapada Atthakathā* referred to gold-brick, gold-plate and vessels of gold, silver, copper and bronze or *kāmsa* It also mentioned (Vol.1, p.79) about the traders or *kāṁsakuta* who cheated with false metals, i.e., selling brass metals for gold. Brass is yellow like gold, and this reference shows that not only bronze, but brass also was indicated by the word *kāṁsa*.

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7

A Millennium of *Ratnaśāstra* (Gemmology) Literature in India

INDIA has always been a land of precious gems. Harappan sites, specially Mohen-jo-Daro, have yielded, on archaeological excavations, a bewildering variety of gems of different types and diverse origins. After the collapse of the Harappan civilization and eastward migration of population from the valley of the (drying up) Sarasvatī river, Indian society took more than a millennium to re-organise itself in the sub-continent.

The first millennium BC in Northern India started with the second phase of urbanisation, and during the middle of this period, the contacts with the South India, Aechemenid empire in Persia and Afghanistan resulted in exploitation of internal mineral resources, import of gem minerals and their processing. The previous chapters contain references to the gem minerals mentioned in the Vedic and post-Vedic literatures, *Aṣṭādhyāyī*, *Kauṭilīya Arthaśāstra*, the epics, the Buddhist and Jaina canonical texts, etc. Gemmology as a subject was however developed only in the post-Christian era.

Some Key Indian texts containing references on gemmology or *ratnaśāstra* have been listed in Table 7.1. Some of the dates given in the table are approximate. The rise of monarchial powers, urbanisation and international trade resulted in widespread imports and exports of gem minerals. Many battles and conquests took place for acquisition of fertile lands as well as mines of precious metals, ores, and gem minerals.

The second century AD Tamil text *Silappadikaram* was one of the early literatures which recorded the grandeur of the gem markets in India and the Indo-Roman trade related to gems. During and after the ascendency of the Gupta Period, outstanding Sanskrit literatures on gemmology such as *Brhat Saṁhitā*

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(*Bṛ. Saṁ.*), *Ratnaparīkṣā* (*RP*), *Agastimata* (*AM*) etc. were published. Some Prākṛt literatures like *Aṅgavijjā* are also worthy of notice. One millennium of Indian studies on gems culminated in the thirteenth-fourteenth centuries AD compendium texts such as *Rasaratnasamuccaya* (*RRS*), *Rayaṇaparikkhā* (*RYP*). In the nineteenth century, S.M. Tagore published *Maṇimālā* (*MM*), a beautiful collection of extracts from the earlier Sanskrit texts related to *Ratnaśāstra*.

Table 7. 1

Some Indian Texts Containing References to Gemmology (*Ratnaśāstra*)

End of the 4th century BC	*Kauṭḷīya Arthaśāstra* (*AS*)
300 BC	*Mahāvagga/Cullavagga* references to Beryl
200 BC	Jaina Canonical text *Ācāraṅga Sūtra*
End of 2nd century AD	Tamil text *Śilappadikaram*
AD 270	*Yavanajātaka* of Sphujidhvaja. The earlier Greek text dated AD 150
4th century AD	*Aṅgavijjā*, the text in Prākṛt on prognostication, *Kāmasūtra* of Vātsyāyana
AD 450	*Amarakośa* (*AK*), the lexicon of Amarasiṁha
AD 505	*Bṛhat Saṁhitā* (*Bṛ. Saṁ.*) of Varāhamihira
Early 6th century AD	*Ratnaparīkṣā* (*RP*) of Budhabhaṭṭa
Late 6th century AD	*Agastimata* (*AM*)
8th century AD	*Nītisāra* and *Garuḍa Purāṇa* (*GP*)
AD 1075	*Yuktikalpataru* of Bhoja
AD 1130	*Mānasollāsa* (*ML*) of Someśvara
AD 1250	*Rājanighanṭu* (*RN*) of Narahari
AD 1260	*Navaratnaparīkṣā* (*NRP*) of Nārāyaṇa
13th century AD	*Rasaratnasamuccaya* (*RRS*) of Vāgabhaṭācārya.
AD 1315	*Rayaṇaparikkhā* (*RYP*) of Ṭhakkura Pherū
AD 1879	*Maṇimālā* (*MM*), compilation by S.M. Tagore

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Categorisation of Gems

Kauṭilīya Arthaśāstra of the pre-Christian era presented a list of gems which has been mentioned by us earlier in chapter 5. The principal categories stated therein are colourless quartz (*sphaṭika*), red ruby (*padmarāga*), blue sapphire (*indranīla*), green beryl (*vaidūrya*) and yellow topaz (*puṣparāga*), apart from several minor ones. Diamond (*vajra*), pearl (*muktā*) and coral (*pravāla*) were considered separately.

Over the centuries, the pattern of categorisation of gems did not alter very much. The thirteenth century text *RRS* (4.4-4.7) listed five principal gems or *pañca-ratna*: *vajra*, *padmarāga*, *indranīla*, *puṣparāga* and *marakata* (the last one is emerald, a deeper green variety of beryl or *vaidūrya*). During the Gupta era, the *Bṛ. Saṁ.* (80.2-5) listed 22 gems of which nine were principal ones (*navaratna*) representing nine planets (*navagraha*).

Ancient Categorisation Viewed in Terms of the Modern Science

It is obvious that gems have been prized principally in terms of their lustre and colour. The ancient gemmologists realised that different minerals might have similar colour, and therefore identification of gem minerals involved at least one more parameter. Hardness of minerals was a very valuable guide in identification of gems, specially in view of the fact that the modern indices of evaluation such as specific gravity, refractive index, X-ray diffraction pattern, etc. were not known in the ancient days.

Table 7.2 provides the list of principal gems which were known and used in the ancient world. These gem minerals have been arranged in the decreasing order of hardness (Moh's Scale). Energetic chemical bonds, often of the covalent type, result in hardness, which in turn provides the necessary durability of gem minerals. Such materials may have high refractive index and lustre but are usually colourless when completely devoid of impurities. Table 7.2 shows how trace quantities of idiochromatic transition elements such as Fe, Cr, Mn, Ni, Co get into the hard but colourless networks and alter their colour drastically. Nassau (1983: 23 and 333-36) has explained that not less than 13 out of the possible 15 causes attribute colours to minerals and gemstones.

Naturally, different categories of gems may, and do turn out to have similar colours, and in such cases, determination of hardness of the sample by scratch test has been a very useful exercise in the identification of the gem. Gemmology has always involved the art and science of imitation, and detection of clever imitations. Coloured glass was invented in India to imitate beryl and other precious stones (Pliny 37.26) and therefore it became a nuisance in the gem

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Table 7. 2

Gem Categories of Importance in the Ancient World

Name English/Sanskrit	*Colour*	*Hardness (Moh's Scale)*	*Reasons for Non-white Colour*
Diamond/*vajra*	usually colourless	10	Blue due to boron, yellow/green due to nitrogen
Corundum/ *kuruvinda*	usually colourless	9	Pure Al_2O_3 is colourless. Trace impurities make it ruby or sapphire.
Ruby/*padmarāga*	red	9	Cr^{3+} replaces Al^{3+}. Transition involving ligand field effect
Sapphire/*indranīla*	blue	9	Four different mechanisms including charge transfer; combination of Fe and Ti
Non-blue *sapphire*		9	Orange *padparadsca* (Mg^{2+} and Cr^{4+} replacing two Al^{3+} ions); same colour (due to Ni and Cr); yellow *karundaka* (only Ni); green (due to Co, V and/or Ni); asterism or star sapphire (due to Ti).
Chrysoberyl/Cat's eye *mārjārakṣaka/ laśunia*	green/yellow	8-½	Green due to Cr and yellow due to Fe substituting in Be Al_2O_4 structure.
Spinel/Balas-ruby/ *bālasūryaka*	rose-red	8	Pure spinel Mg Al_2O_4 is colourless, Cr^{3+} substitution makes it rose-red. Fe and Mg may further alter the colour.
Topaz/*puṣparāga* also puṣyarāga	Yellow	8	Pure topaz is colourless $[Al(F,OH)]_2 SiO_4$. Yellow colour is due to impurities — ferrous oxide, lime and alkali. Dichroic, also blue.
Beryl/*vaidūrya*	Faint green water colour	7-¾	Pure beryl $Be_3 Al_2 Si_6O_{18}$ is colourless. Faint green due to substituting Cr^{3+} This is allochromatic effect — transition involving ligand field.
Emerald/*marakata pannā*	Deep grass green	7-¾	This is beryl containing more Cr^{3+} imparting green colour. Dichroic, the second bluish colour is due to iron.

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Name English/Sanskrit	*Colour*	*Hardness (Moh's Scale)*	*Reasons for Non-white Colour*
Aquamarine/ *pāribhadra*	Faint blue to bluish green	7-¾	Bluish tinge due to iron.
Zircon/*gomed*	Cow-flesh/ colour	7-½	Pure zircon $ZrSiO_4$ is colourless. Reddish-yellow colour of Hyacinth is due to Fe^{3+}, decolourised on reduction to Fe^{2+}
Garnet/*tāmrya* or *tāmḍi*	Various colours	7-¼	Family of minerals $M_3^{2+} . M_2^{3+} . (SiO_4)_3$. Colour depends upon chemical composition. Hessonite is confused with Hyacinth. Colour due to iron.
Tourmaline/ *vaikrānta*	Various colours	7-¼	$H_9Al_3 (B.OH)_2 Si_4O_{19}$ pure tourmaline is light coloured. Fe^{2+} and Cr^{3+} make it dark green, Mg makes it brown and Mn dark red.
Quartz/*sphaṭika*	Colourless	7	Pure SiO_2 is colourless. Yellow citrine due to iron; green chrysoprase due to nickel, violet amethyst due to manganese etc.
Agate/*akīk* Carnelian/ *Rudhirākhya*	Light colour Red	6-½	Hydrated SiO_2 is colourless. Hydrated ferric oxide as impurity makes it brown or yellow. Heating causes dehydration and ferric oxide gives red colour to carnelian.
Olivine/Chrysolite/ Peridot/*puttikā*/ *jabarjad*	Bottle green	6-½	Pure Mg_2SiO_4 is colourless. Replacement of part of MgO by ferrous oxide makes it yellowish green. Mn^{2+}, Ni^{2+} further change the colour.
Orthoclase/Feldspar Moonstone/*candra-kānta*; Sunstone *suryakānta*	Opalescent; play of Colour	6	Interference of light from thin tayers.
Jade/*pīlu*	White green black	5-½ - 7	Green due to Mn and Cr and Fe^{2+}. Black due to Fe^{3+}.
Turquoise	Blue	6	The mineral is a derivative for ortho-phosphoric acid, the hydrogen atoms replaced by radicals such as $Al(OH)_2$, $Fe(OH)_2$ (providing green tinge) and Cu(OH) (providing intense blue colour).

(*Contd.*)

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Name English / Sanskrit	*Colour*	*Hardness (Moh's Scale)*	*Reasons for Non-white Colour*
Lapis Lazuli/Ultra marine/*rājāvarta/ lajhward* (Glass has hardness 5-5-1/2)	Deep azure blue	5-½	The constituent minerals are Sodium-Calcium-Aluminium silicates with sulphate and polysulphide (S_3) anions. The 19 outer electrons of S_3 unit undergo transitions within the molecular orbitals. These produce absorption band in the yellow range and hence intense blue colour. Less sulphur in the mineral system gives green colour which makes the gem less worthy.
Pearl/*muktā*	Usually white	3-4	Iron, manganese etc. possibly complexed with organic matter, so that the colour is perishable on heat.
Coral/*pravāla/ vidruma*	red, black etc.	3-4	Iron, manganese etc. possibly complexed with organic matter, so that the colour is perishable on heat.

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industry. However this could be easily detected since the material glass has a low hardness of 5. On the other hand, distinguishing between zircon (7-1/2) and garnet (7-1/4) of similar colour and little difference in hardness required careful streak tests.

The Scope of *Ratnaśāstra* (Gemmology)

AM (3-4) outlined the scope of the *Ratnaśāstra* texts:

> उत्पत्तिम् आकरान् वर्णान् जातिदोषगुणाम् स्तथा
> मूल्यम् माण्डलिकम् चैव ग्राहकं हस्तसंज्ञया
> *utpattim ākarān varṇān jātidoṣaguṇām stathā*
> *mūlyam māṇḍalikam caiva grāhakam hastasaṃjñayā*

The theory of origin (*utpatti*) of the gems was shrouded in the extravagant emphasis on a myth which we would discuss later. The texts discussed *ākaras* or the mine-sites. The colour and 'castes' (categories) of individual gems were mentioned. The defects of gems and the qualities of excellent gems were specifically discussed. In order to be acceptable, the gems must have well-defined and uniform colour, lustre and geometrically defined crystal shapes. There must be appropriate directionality of radiance when a gem is held against the sun (*AM*, 213).

RRS (4.33) mentioned five typical *doṣas* or defects of gems:

> ग्रासः त्रासश्च बिन्दुश्च रेखा च जलगर्भता
> *grāsaḥ trāsaśca bindusca rekhā ca jalagarbhatā*

Grāsa means black spot, *bindu* black spot due to erosion, *rekhā* line and discolouration, *jalagarbhatā* refers to bubbles. *Trāsa* means grain boundaries; *ML* (2.4.423) defines this term as *bhinnabhrāntikara*, creating an illusion of being broken. *Satrāsa* means a gem with fractures.

Many *Ratnaśāstra* texts discuss the norms of price fixation (*mūlya*) of gems. However, *Agastimata* (61-75) is the only text which discusses the qualifications of an expert of gems or a gemmologist, titled *maṇḍalika*, and the various hand-signs (*hastasaṁgā*) by which he negotiates transactions with the *grāhaka* or the customer, thereby crossing language barrier.

Item-wise Discussion on Gems with Decreasing Hardness

DIAMOND (10)

Diamond (*vajra*, later also known as *bhidura* and *hīraka*, *hīrā*) was known as

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the hardest gem or mineral. Its property became proverbial in Bhavabhuti's *Uttara Rāmacarita* (2.7): *vajrādapi kaṭhorāṇi* . . . . 'something tougher or harder than even diamond'. Apart from its gem quality, diamond was used as an abrasive. It was mentioned in the *Maṇilakṣaṇa* chapter of the *Skanda Purāṇa* (*SP*, 23.79) that diamond cannot be scratched by any other gem.

Various texts (*AS*, 2.11; *Bṛ. Saṁ.*, 79.10) referred to streams, mines and placer deposits as the sources of diamond: *srotaḥ khaniḥ prakīrṇakam.*

All the manuals listed eight sources of diamond, but as Finot suggested, several of these were trading places and not actual mining areas. The bank of the Veṇā (Wainganga near Nagpur) had diamond mines; the place seems to be Wairagadh formerly known as Vajragṛha. This place, the area of Vidarbha, had been mentioned by Kauṭilya as Sabhārāṣtra. Kosala or South Kosala meant the Bundelkhand area around Pannā; the diamond field of this area tempted many invaders such as the Kuṣāṇa King, Kaniṣka. Mataṅga is the tract between Kṛṣṇā and Godāvarī, including the area of the Golconda mines. Kaliṅga included the Mahānadī alluvium in the Sambhalpur district of Orissa. (Shastri, 1969:325-27)

Good diamonds were supposed to be *ujjala* or bright, *adoṣa* flawless, *amala vāritara* free from impurities and transparent like water. Rain-bow like colour, *ambudendradhanuḥ* was a desirable property (*RRS*, 4.27). Ibn al-Afkānī, an Arab gemmologist, commented: "Indians prefer white and yellow diamonds because of the red rays, that emanate from them when viewed against the sun, and the spectrum resembling the rainbow". (quoted by Sarma, 1984:48)

Śilappadikaram was probably the first text classifying diamond into four 'castes': brāhmaṇa, white and light yellow; kṣatriya red; vaiśya dark yellow or smoky and śūdra, black or impure. This casteist slant in gemmology persisted for more than a millennium.

Another mehtod of categorisation was in terms of the crystalline properties. Pure diamond crystal was known to be octahedral, with eight symmetric facets (*samaphalaka*), twelve sharp edges (*dhārā*), six prominent solid angles (*koṇa*):

षट कोणा अष्ट फलका द्वादश धारा: सन्ति वज्रे च . . .।
. . . समफलकम् उच्चकोणं सुतीक्ष्णधारं च वारितरम् अमलम्।।
ṣata koṇā aṣṭa phalakā dvādaśa dhārāḥ santi vajre ca . . .।
. . . . samaphalakam ucchakoṇaṃ sutīkṣṇadhāraṃ ca
vāritaram amalam ।। (*RYP*, 23-24)

Defective diamonds apart from having flaws such as crow's foot (*kākapada*), spot (*vindu*), streak or line (*rekhā*), impurities (*samala*), etc. may also be geometrically

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defective (*RYP*, 25; *AM*, 27). Such defective samples may be barley-shaped (*yavākāra*), broken (*sphuṭita*) such that these have unequal solid angles (*hinādhikakoṇaṁ*), sometimes only one solid angle (*ekaśṛngaṁ*) or even roudness (*vartulaṁ*). On this consideration, *RRS* (4.26-28) classified diamond gems into three genders or categories — masculine, feminine and neutral. The samples with well-defined facets, edges and angles are 'masculine'. The feminine samples are concave, flat or cylindrical. The neutral (*napuṁsaka*) samples are spherical or blunt at the tips and slightly heavy.

RRS typified most of the *Ratnaśāstra* texts while endorsing sex- and caste-based chauvinism. It not only divided diamond (and most other gem categories) into 'castes' (based on clour) and 'genders' (based on geometrical features) but also recommended that persons of specific caste and gender should use diamonds of the corresponding type **only**. It went further, and noted with an air of conclusion that categorisation of all objects into castes and genders is of universal applicability.

स्त्री पुं नपुंसकं वज्रं योज्यं स्त्रीपुन्नपुंसके
श्वेतादिवर्णभेदेन . . . स्व स्व वर्णफलप्रदम्
. . . पदार्थेषु अखिलेषु अपि।।

strī puṃ napuṃsakaṃ vajraṃ yojyaṃ strīpunnapuṃsake ।
śvetādivarṇabhedena . . . sva sva varṇaphalapradam
. . . . padārtheṣu akhileṣu api ।।

(*RRS*, 4.29-31)

Pricing (*mūlyaṁ*) of diamond and other gems was elaborately discussed in most of the *Ratnaśāstra* texts (*AM*, 49-52; *Bṛ. Saṁ*. 79.12-16; *RP*, 39; Finot, xxx). From the data, it appears that price of diamond (in *kārṣāpaṇas*) per unit mass (in *taṇḍulas*) varied approximately with the square of the mass. With a tenfold increase in mass (from 2 to 20 *taṇḍula* or 4 carats) price per unit mass increased 100 times (200 to 2 lakh *kārṣāpaṇas*). Thus absolute price increased proportionately with the cubic power of the mass of the diamond sample. The price came down with various kinds of defects which were listed.

While *Bṛ. Saṁ.* and *RP* fixed the price of diamond on the basis of weight only, *AM* (42 and 49-52) suggested that volume should also be considered. Ideally, a piece of diamond having the volume of a barley grain should have the weight of a grain of rice (*AM*, 42). Evidently, specific gravity was recognised as an important consideration. *AM* and subsequent literatures (*GP*, 68.38 and 47; *MM*, 139) have created confusion by commenting that lighter diamonds are necessarily better and hence more valuable. *Agastimata* or *AM* (49-52) suggested that the specific gravity of diamond could vary within the range — 75 + 25 per

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cent; this is 'pure imagination' in the words of Finot. The comment in *AM* 50: *tripādam tarate toye*, i.e., a diamond floats on water when it weighs three quarters less than the ideal mass for the same volume', is very useful since it implies *Agastimata's* opinion that diamond is four times denser than water, or that its specific gravity is 4.0 (the true value is 3.52). When it is stated that heavier pieces are impure and hence less valuable, what is implied is contamination of diamond with a heavy mineral such as zircon (sp. gr. average 4.68). That a diamond piece having lower weight per unit volume or specific gravily should fetch more price (*AM,* 49-52) was a preposterous suggestion, because such a piece would also be grossly impure. (Sarma, 1984: 50-53) The text in *AM*, 50, quoted before, was seriously misunderstood, and *Garuḍa Purāṇa* (68.38) even commented that a good piece of diamond should float in water!

CORUNDUM, RUBY AND SAPPHIRE (9)

It has been indicated in Table 7.2 that pure corundum (*kuruvinda*) is colourless, and specific lattice substitutions in Al_2O_3 induce specific colour and produce gems such as red ruby or *padmarāga*, blue sapphire or *indranīla*, etc. These three minerals have high hardness (9), and only diamond is harder than them (*AM*, 238). Kauṭilya mentioned the use of *kuruvinda* as an abrasive (*AS,* 2.14.48).

Buddhabhaṭṭa made an interesting statement that ruby and sapphire cannot be scratched by any mineral other than diamond and corundum (*RP*, 137); similar statements have been repeated in *GP*, 1.70.27 and *MM*, 213:

कुरुविन्दं तथा वज्रं विमुच्य अन्येन केनचित्।
न शक्यं लेखनं कर्त्तुं पद्मराग इन्द्रनीलयोः।।
kuruvindaṃ tathā vajraṃ vimucya anyena kenacit ।
na śakyaṃ lekhanaṃ karttuṃ padmarāga indranīlayoḥ ।।

Sarma (1984: 51-52) has expressed surprise in the above statements since ruby and sapphire have the same Al_2O_3 lattice as corundum, and are supposed to have similar hardness. However trace substitution by low energy oxides of Cr, Fe etc. might lower surface free energy and hardness of Al_2O_3 by a small amount, and this may be detectable when pure corundum powder is mounted on a grinding wheel. Bauer (1968: 282) has reported slight differences in hardness values of the varieties of corundum, and the fact that ruby is slightly softer than sapphire.

Padmarāga or red ruby used to come to the ancient India from the gem-beds of Sri Lanka. The valley of the river *Rāvaṇagaṅgā*, overgrown with Areca-palms was strewn with varieties of ruby (*GP*, 1.70.3-17). *Padmarāga* was also known

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as *māṇikya* and *cunnī* (from *cūrṇikā*, small pieces). Best ruby has been described as red like lotus (*padmarāga*), transparent, brilliant, heavy and clear. *Agastimata*, 213 classified ruby on the basis of the amount of radiance emitted above, below and on sides, when held against the sun. If the radiance spreaded all around, indicating lack of crystallinity, then the piece was considered to be spurious (*RYP*, 68).

Ruby was known to exist in different shades of red. *Padmarāga* was the red variety with a tinge of white, *nīlagandhi* red with a blue or black tint, *saugandhika* yellowish red. The last one was probably known in the West as the orange *padparadsca* (a corrupt form of the word *padmarāga*), the yellowish aurora-red gem from Sri Lanka. (Herbert Smith, Gemstones pp. 289-90) Dull-hued red variety 'with its lustre remaining within' was sometimes called *kuruvinda* (*GP,* 1.70.13). Crimson-yellow variety was known as *karundaka* or *kaurandaka* (*MM,* 407; *GP,* 1.74.2). A transparent variety slightly red and yellow was known as *kāṣāyaka* (*RP,* 218; *GP,* 1.74.3). A red variety which appeared to be smeared with milk (*dugdhaliptasma*) was defined as *laśunapadam*, like *laśuna* or garlic (*NRP,* 115).

Rose-red balas-ruby belongs to an altogether different category. It is not Al_2O_3 but a spinel or mixed oxide, $MgAl_2O_4$. It is softer than ruby, its hardness being eight in the Moh's Scale. Like Al_2O_3, it is colourless when pure, chromium substitution making it red. Spinels come in a wide variety of colours, but here we are concerned with rose-red spinels which have been known as balas-rubies or *rubis balais*. Spinels are abundant in the ruby mines of Badakshan. In the thirteenth century AD, Marco Polo collected spinels with rubies in the province of Balascia on the Upper Oxus, which is identical with the Badakshan of the present-day. Bauer writes (1968: 298) that the term 'balas-ruby' is derived from the place-name Balascia. However, we propose that both these names were derived from the Sanskrit term *bālasūryaka*, the crimson-coloured morning sun. Kauṭilya mentioned *bālasūryaka* as a variety of *padmarāga* or ruby (*AS*, 2.11.29). Thus it is quite likely that ever since Kauṭilya's time, the Indians were familiar with the spinel ruby mines of Badakshan. These mines remained famous for more than a millennium. In 1315, Ṭhakkar Pheru wrote :

> अतितेजः अग्निवर्णं लालं बंदंखसाण देशे
>
> *atitejaḥ agnivarnam lālam bandamkhasāṇa deśe*
>
> (*RYP*, 104)

At that time, spinel ruby was known as *lāl*. At times, ruby (9), spinel ruby (8), hyacinth variety of zircon (7-1/2) and hessonite variety of garnet (7-1/4), appeared to have similar reddish yellow colour, but these could be easily

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distinguished from one another by scratch tests since their hardness values (given in parenthesis) are different.

Indranīla or sapphire was known to the Indians as a different category of gem-mineral (*AS*, 2.11.31), but we know now, that this is blue corundum (vide Table 7.2). According to Buddhabhatta (*RP*, 195-196; also supported in *GP*, 1.72.17-18 and *MM*, 405), a sapphire in which the colours of the rainbow sparkle is an *indranīla*, and the one which turns the milk in a bowl blue, is a *mahānīla*. The *Agastimata* however labels the second variety as *indranīla* (*AM*, 268), the sapphires from Sri Lanka *mahānīla* and the rest of the sapphires from other sources as plain *nīlas*. *Utpala*, mentioned in *Arthaśāstra* and *Maṇimālā*, is greenish blue and could be aquamarine rather than sapphire.

The *Ratnasāstra* texts described *indranīla* occurring in different shades of blue, and we know today that sapphire can be deep-blue, the most admired tone being 'intense cornflower-blue'. Sapphire could be whitish blue leuco-sapphire or *somānaka* (*RP*, 219; *GP*, 1.74.3) or possess a yellowish tinge ('Oriental topaz'). We have already mentioned that sapphire is slightly harder than ruby (Bauer, 1968: 282). The word 'sapphire' came from the old Arabic (also Hebrew) 'sapeer' meaning 'to scratch', something which is hard. Its hardness enabled it to be distinguished from less hard blue gems like aquamarine, lapis lazuli, and blue-coloured materials like quartz, glass or marble (*GP*, 1.72.14). *Garuda Purāna* mentioned various defects (grain boundary, holes etc.) of some sapphire samples, their occasional contamination with mica and moderate thermal resistance (*GP*, 1.72.6 and 11). The Indians received the best variety of sapphire from the Padmākara province of Sri Lanka (*MM*, 397), which must have been around the modern Ratnapura on the Kaluganga.

Like blue to yellow transition, sapphire was known to have blue to red transition also, and such reddish blue coloured corundum samples could be called either sapphire or ruby. As a matter of fact, the Arabs guessed (without any scientific knowledge) that sapphires and rubies belonged to a transitional single group of gem mineral, and they called this *Yāqūt* which, according to Al-Afkānī, occurred in seven varieties. (Sarma, 1984:61; Wiedemann, 836-40) Both ruby and sapphire crystals, specially the dark coloured ones, are dichroic, i.e., appearing differently coloured when viewed through mutually perpendicular axes. The famous 'Sapphire Marveilleux' appears blue by day and red amethystine by night (*Maṇimālā*, p. 459). Sapphire with a dash of red has been known as *tittibha* (*MM*, 423) A deep blue gem dashed with red was known as *nīlāṅga* or violet-ruby (*Maṇimālā*, part 2, pp. 514-15).

Asterias or star Sapphire is a special variety which when viewed against light appears like a six-rayed chatoyant star. This is due to the reflection of light

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from the surface of a multitude or microscopically small tubular cavities or rifts enclosed in the crystal, and grouped into three sets, each of which is parallel to a face of the hexagonal prism. (Bauer, 1968: 284) This variety of *indranīla* was mentioned by Kauṭilya as *śravanmadhya* (*AS*, 2.11.31) which has been interpreted by one Sanskrit commentator as streaming interior or 'having rays shooting like flowing water'.

Most *Ratnaśāstra* texts have discussed the pricing pattern of rubies and sapphires. Sapphire was considered to have different shades of colour which were equated to 'castes', e.g., whitish blue (brāhmaṇa), reddish blue (kṣatriya), yellowish-blue (vaiśya) and black-blue (śūdra) etc. (*RYP*, 82).

GEM MINERALS CONTAINING BERYLLIUM

We would now discuss the family of gem minerals containing beryllium, variously coloured, specially green and blue, and having similar hardness. In terms of chemical composition, a sharp distinction has to be made between chrysoberyl (hardness 8-1/2) $BeAl_2O_4$, a mixed oxide, and beryl (hardness 7-3/4) $Be_3Al_2Si_6O_{18}$ a cyclo-silicate. The difference in their hardness could be easily tested using another gem, topaz having an intermediate hardness of eight. In absolutely pure form, both chrysoberyl and beryl are colourless. Their colours in the gem form arise on account of lattice substitutions by other elements as specified in Table 7.2. Due to chromium and iron, chrysoberyl samples assume green and yellow colour respectively, the more usual green colour often merging into golden yellow.

Milky white or greenish white cloudy chrysoberyl samples (not the clear and transparent ones) exhibt chatoyancy. Extending across the curved surface of such stones is a silvery line or streak of light, when viewed in a strong light. These samples are called chrysoberyl or oriental cat's eye. The phenomenon of chatoyancy is due to the existence in immense numbers of microscopically small cavities arranged in a particular direction or a bundle of microscopic channels running parallel to a single direction. When viewed at right angles to this direction, a band of light is visible running across this bundle. The stone is usually cut along this direction so that maximum number of light-reflecting cavities are close to or on the surface producing maximum chatoyancy.

Quartz cat's eye samples (hardness 7) show similar chatoyancy or a wave of milky light reflected from the surface, the effect in this case arising due to the presence of large number of fibres of asbestos aligned in a specific direction.

Beryl, *vaidūrya* in Sanskrit, has a hardness (7-3/4) different from those of chrysoberyl (8-1/2) and quartz (7), and the modern literature does not indicate

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that chatoyancy is observed in any beryl sample. However, green chrysoberyl sometimes looks like green beryl, and since the former gem exhibits chatoyancy effect occasionally, the Indian word *vaidūrya* has in some instances been used (unfortunately) to indicate cat's eye gem also. We would like to elaborate this point with some details.

Pāṇini referred to *vaidūrya* coming from Vidura. Later Patañjali, the commentator of *Astādhyāyī*, explained that the gem actually came from the Vālavāya mountains, and was only processed in the town of Vidura (which must have been located somewhere in South India). Centuries later, Buddhabhatta wrote about Koṅgavālikasīmanta near the Vidura mountain as the source of beryl or *vaidūrya* (*RP*, 199):

अविदूरे विदूरस्य गिरेः उत्तुंगरोधसः।
कोंगबालिकसीमन्ते मणेः तस्याकरः अभवत्।।
avidūre vidūrasya gireḥ uttuṅgarodhasaḥ ।
koṅgabālikasīmante maṇeḥ tasyākaraḥ abhavat ।।

Sarma (1984: 68) opined that the etymological link between Vidura and *vaidūrya* was 'a fiction invented by the grammarians', but we do not agree with him, since Patañjali's explanation has been clear enough. Patañjali's *vālavāya* (mountain) is similar to Buddhabhaṭṭa's *vālika*.

It is well-known that Koṅga kingdom once governed the beryl mine of Coimbatore of the Salem district from which beryl gems were supplied to the Romans. Alfred Master has suggested ('Indo-Aryan and Dravidian', In *Bulletin of the School of Oriental and African Studies*, Vol. XI, 1943-46, pp. 297-307) that the *veluriya*, the Pāli word was actually a Dravidian word preceding Pānini's *vaidūrya*, and both were the adjectival forms of *Vēlur* (or modern Belur), which is in the heart of the beryl mines of Coimbatore. The AD 500 inscription of the Gaṅga king Durvinīta mentions both Vēḷur as well as the Punnāta kingdom described by Ptolemy as 'Punnāṭa in which is the beryl'. Vēḷur might have been known to Pānini as Vidur ('the far away city') where the beryl gem from the nearby mountains were processed.

Thus, the identity of *vaidūrya* with beryl is well-established. It was known to be quite different from cat's eye. Kauṭilya listed beryl *vaidūrya* and cat's eye *mārjārakṣaka* as distinctly separate gem (*AS*, 2.11.30 and 39). Kauṭilya never mentioned *marakata* (emerald, the darker green variety of *vaidūrya* or beryl) which used to be imported to India from Egypt probably after his era. In the post-Christian era, we find *vaidūrya* and *marakata* being mentioned together to mean the same family of green gem.

Probably Buddhabhatta's writing had created for the first time the confusion

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vis-a-vis beryl and cat's eye. He wrote (*RP*, 200) :

वैदूर्यरत्नमणयो विविध अवभासा:
तस्मात् स्फुलिंगानि वहा इव सम्भवन्ति
vaidūryaratnamanayo vividh avabhāsāh
tasmāt sphuliṅgāni vahā iva sambhavanti

According to this text, *vaidūrya* is many-hued and one variety appears to have specks of fire on the surface. Finot translated this as "comme un jaillissement d'étincelles" indicating chatoyancy, and equated *vaidūrya* with cat's eye. Buddhabhaṭṭa's description indeed reminds one of chrysoberyl cat's eye. Possibly, he made the mistake of using the term *vaidūrya* in a wide sense. This is obvious when he refers to a wide range of colour for *vaidūrya*: the conventional green (*RP*, 203), blue as well as golden red (*RP*, 202 and 208). Finot was certainly wrong (1898 : xlv-xlvii, and 43-45; also *Agastimata* Appendix 9 quoted by Finot in p. 135) in equating *vaidūrya* with cat's eye. At any rate, this confusion had started with Buddhabhaṭṭa, and as Sarma (1984: 68) pointed out, Māgha made a similar mistake in using the word *vaidūrya* to indicate *biḍālekṣaṇa* or chatoyancy of cat's eye (*Śiśupālavadha*, 3.45). *RRS*, 4.57 description of *vaidūrya* is actually that of cat's eye. As we have indicated earlier, the confusion arose probably due to greenish chrysoberyl cat's eye and beryl occurring at times in the same matrix.

The confusion was however not perpetuated. Kālidāsa gave the right description of *vaidūrya* by referring to its long columnal (*ratnaśalākā*) grass-green crystals (*Kumārasaṁbhava*, 1.24). Chrysoberyl was rightly recognised as a separate mineral *karketana*, by Buddhabhaṭṭa himself *rudhira hemamadhuprakāśam* (*RP*, 222; also 221-30). This gem was known to be 'uniformly coloured, light-red like copper or yellow like honey' (*MM*, 426). *Garuḍa Purāṇa* describes it as possessing 'burning fiery brilliance of honey, shedding brilliant rays as if heated in fire' (*GP*, 1.75.2 and 4) which reminds us of Buddhabhaṭṭa's *Sphuliṅga bahā* (*RP*, 200), a description wrongly assigned to beryl (it could represent golden beryl, a gem softer than chrysoberyl but occurring with beryl). *Pāribhadra*, 'a transparent water-green gem' was equated by Tagore (*Manimālā*, part 2, p. 509) to aquamarine, a variety of beryl; it could be chrysoberyl also.

We have earlier described the modern scientific observations on milky white chrysoberyl cat's eye and quartz cat's eye. These were known to Kauṭilya as *mārjāraksaka* (*AS*, 2.11.39) and in *Navaratnaparīksā* as *laśuna* or garlic-like appearing as *dugdhaliptasma* or smeared with milk:

दुग्धलिप्तस्मम् यत् तु लशुनपदम् उच्यते

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dugdhaliptasmam yat tu laśunapadam ucyate
(*NRP*, 115 in Finot, p. 160)

Pheru described the chatoyancy of this gem accurately by comparing it with a human body that has horripilation *pulaka* or has the hair erect and aligned:

लशुनकः बिड़ालाक्षः सपुलकम्।

laśunakah biḍālākṣaḥ sapulakam ।
(*RYP*, 93)

The one which is cat's eye with horripilations.

Thus we cannot agree with Finot that *vaidūrya* is cat's eye, and *lahśuniyā* or *laśunaka* its synonym. As a matter of fact, Alfred Master (quoted by Sarma, 1984: 67) has proved on the basis of a number of Pāli, Prākrt and Sanskrit passages that *vaidūrya* has the clear sense of beryl ('Indo-Aryan and Dravidian' by Master, In *Bulletin of the School of Oriental and African Studies*, Vol. XI, 1943-46, pp. 297-307). Occasional identifications of *vaidūrya* with cat's eye (such as in *Maṇimālā*, 226, 228) have been erroneous and unfortunate.

VAIDŪRYA AND MARAKATA

Kautilya was the first to describe the *vaidūrya* gem:

वैदूर्य उत्पलवर्णः शिरीषपुष्पक उदकवर्ण वंशरागः शुकपत्रवर्णः

vaidūrya utpalavarṇah śirīṣapuṣpaka udakavarna vaṁśarāgaḥ śukapatravarṇaḥ (*AS* 2.11.30)

Beryl is of the colour of the blue lotus, of the *śirīṣa* flower, of the colour of water, green bamboo, parrot's wing.

While describing beryl as many-hued, Buddhabhaṭṭa emphasized that its principal colours resembled the neck of the peacock and greenness of bamboo (*RP*, 203) : *śikhikantha nīla veṇudala prakāśa*.

Agastīya Ratnaparīkṣā, 78 mentions

शुकपत्र वंशपत्र शैवालहरिता दूर्वापत्रनिभा खद्योत पृष्ठ संकाशा

śukapatra vaṁśapatra śaivālaharitā dūrvāpatranibhā khadyota prstha saṁkāśā

Similar description has been provided in *GP*, 1.73.6-7. In chapter 6, we have presented extracts from the *Mahābhārata* which describe the nature of colour of the light and deep green blue beryl-cum-emerald-cum-aquamarine, which

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belong to the same family.

The family of beryl is a cyclosilicate $Be_3Al_2Si_6O_{18}$ which crystallises in the hexagonal system, sometimes occurring as long six-sided prisms, terminated by a basal plane (vide Kālidāsa's long grass-green *ratnaśalākā* mentioned before). In pure form, beryl is colourless. Lattice sustitution by a very small quantity of chromium (in the form of Cr^{3+}) makes the crystal light grass-green (typical *vaidūrya* of the early Sanskrit literature). Larger proportion of chromium (typically 0.2 per cent or above) results in intense green colour: 'beautiful and deep emerald-green to grass-green, unrivalled in depth and brilliancy and comparable to the fresh green of a meadow in spring'. (Bauer, 1968: 308) This variety is well-known as **emerald** or *marakata* which was not mentioned by Kautilya, and the best samples were imported later to India probably from Ethiopia, Egypt, and during the Muslim period, from Turkey. Lattice substitution by iron to the extent of 1/2 to 2 per cent makes the crystal light blue, and such natural crystals have been known as aquamarine or *pāribhadra*. Greenish blue *utpalavarna* in *AS*, 2.11.30 an *indīvara śyamavapu utpala* in *Manimālā* (p. 510) is likely to be aquamarine. Ancient India was famous for the light-green as well as light blue beryl/aquamarine, the best supplies originating from Paddur, Kangayam and several other sites in the Coimbatore district. Beryl is also known to occur in yellowish green and pure golden yellow colour.

Marakata or emerald became popular in India only after Kauṭilya's era. Buddhist monks and nuns were asked not to use shoes ornamented with, and bowls set with *vaidūrya*:

न वेलुरियमया पादुका धरितव्वा
na veluriyamayā pādukā dharitavvā
(*Mahāvagga*, 5.8.3)
न वेलुरियमया पठ्ठो धारेतव्वो
na veluriyamayā paṭhṭho dhāretavvo
(*Cullavagga*, 5.9.1)

These were texts dated around 300 BC, in which *marakata* did not appear.

Evidently *marakata* or emerald was imported to India during the onset of the Christian era.

Though the occurrence of emerald in Ethiopia had been known to the ancients, the locality became completely forgotten. The earliest known emerald locality is in upper Egypt, not far from the coast of the Red Sea. The ancient mines discovered by Cailliaud in AD 1819 have been dated as early as 1650 BC; these are located in a depression of the long range of mountains which borders

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the west coast of the Red Sea. The mines are in Jebel (Mountain) Sikait (also Sakketto, from Sanskrit Saikat?) and Jebel Sabara (Zabara or Varvara in Sanskrit). Pliny mentioned the rocks about Coptos, as containing the celebrated mines of the old. These mines, known as Cleopatra's emerald mines, located a little south of latitude 25°N, were close to the sea-coast as well as the desert and known as such by the Indian traders. The name *marakata* bears the imprint of *maru* (desert) and *kata* (from Pliny's 'Coptos' or *saikata* meaning sea-coast or the mountain Sakketto?). In the justification of our hypothesis regarding the origin of word *marakata*, let us quote some *Ratnaśāstra* texts. Buddhabhaṭṭa wrote (*RP*, 150):

तद् वर्वरालयम् अतीत्य मरोः समीपे
स्थानम् क्षितेः उप पयोनिधितीर देशे
तत् प्रत्ययान् मरकत आकरताम् जगाम।।
tad varvarālayam atītya maroh samīpe
sthānam ksiteh upa payonidhitīra deśe
tat pratyayān marakata ākaratām jagāma ।।

The location of the *marakata* mine (*ākara*) past the sea-coast (*tīradeśe*) mountain Varvara and near the desert (*maroḥ samīpe*) has been strongly suggested. Agastimata (287) writes:

विषमस्थाने उदधेः तीरसन्निधौ धरणीन्द्र गिरिः तत्र
viṣamasthāne udadheḥ tīrasannidhau dharaṇīndra giriḥ tatra

and *Ratnasaṁgraha* (13) mentions:

म्लेच्छदेशे महाशैले शुकपक्षनिभ मरकत
mlecchadeśe mahāśaile śukapaksanibha marakata

as the source of *marakata*.

The *Mahābhārata* (12.46.33) has used another name for emerald, and that is *masāragalu, masāra* or *masāraka*. Monier-Williams explains in his Sanskrit Dictionary that Egypt was named as *Misar* or *Misar* in Sanskrit, and *galu* means a gem. Therefore *masāragalu* may be interpreted as the gem from Egypt, and that is consistent with the etymological origin of *marakata* explained earlier. The fourth century AD Prākṛt text *Aṅgavijjā* (58.20) mentions *veruliya, maragata* as well as *masārakalla*.

Emerald has few more name-equivalents in Sanskrit: *harinmaṇi* (green gem), *garuḍodgāra*, *gārutmata*, *pannā*, etc. The last three may be briefly explained. *Ratnaparīkṣā* and *Agastimata* narrated the myth or the folklore that

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gems had been derived from the body of the slain demon Bala: diamond from his bones, pearl from the teeth, ruby from the blood, sapphire from the eyes, emerald from the bile, etc. The mythical bird Garuḍa had taken the green bile of the demon in its mouth and then vomitted it (hence the name *gārutmata* and *garuḍodgāra*) 'on a mountain on the sea-coast near a desert beyond Barbara country'. We have earlier quoted the original Sanskrit text (*RP*, 150). *Agastimata* (285) mentioned Garuḍa as the king of the serpent-demon: *pannagādhipaḥ*. *Panna* also means something fallen down or dropped. Thus, the dropped bile of the serpent-demon or emerald also came to be known as *pannā*. It is an open question whether the location of the famous diamond mine in Bundelkhand was named Pānnā because it also yielded some emerald or *pānnā*. The Sanskrit word *marakata* was the origin of *smaragdos* in Greek, *smaragdus* in Latin, *esmeralda* in Spanish and **emerald** in English.

However, the Egyptian emerald had been known in Europe from a very early date. Herodotus mentioned the emerald colum in the temple of Hercules in Tyre 'emitting a splendid light in night'. Plato mentioned the use of emerald. Aristotle's disciple Theophrastus wrote that '*smaragdos* assimilates the colour of water into which it is thrown to its own colour'. Caesar and Cleopatra met in a hall of tortoise-shell, studded with emerald and topaz gems, Egypt having mines for both. Emperor Nero used to watch the feats of the gladiators, through an eye-glass of emerald. With the onset of the Indo-Roman trade during the first century BC, the Indians, long used to light-green *vaidūrya* or beryl gems, started importing and using the intense green-coloured gem of the same family viz., *marakata* or emerald. Some emerald might have been imported from Turuṣka or Turkey (*MM*, 357) during the Muslim period. The name *tārkṣya* stood for emerald (*RRS*, 4.5); Garuḍa was the son of Tṛkṣa.

The *Ratnaśāstra* texts such as *RP*, 152; *MM*, 377-379; *GP*, 1.71.12-17 described the colour and hue of the best quality emerald, and quite naturally used many of the adjectives and similies applied to beryl and aquamarine:

The peacock's tail, the wing of the *nīlakaṇṭha*, parrot's wing, moss, fresh grass, glow-worm's back, the *śirīṣa* flower and so on. *Agastimata* (299) referred to the important property of emerald 'spreading its green colour all around (*pārśvarañjana*) when viewed against light':

कृत्वा करतले चैव भास्कराभिमुखं धृतम्।
रन्जयेत् आत्मपार्श्व च महामरकतम् स्मृतम्।।
kṛtvā karatale caiva bhāskarābhimukhaṃ dhṛtam ।
ranjayet ātmapārśva ca mahāmarakatam smṛtam ।।

Buddhabhaṭṭa wrote (*RP*, 158-159): 'When sun's rays fall on it, shoots diffusion

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of light all around . . . . infused light makes it appear like a green meadow:

सवितु: करसम्पर्कात् च्छुरयति सर्वाश्रयम् दीप्त्या . . .
. . . अचिरप्रभा समद्युति नवशाद्वल सन्निभ भाति
savituḥ karasamparkāt cchuryati sarvāśrayam dīptyā. . . .
. . . . aciraprabhā samadyuti navaśādvala sannibha bhāti

Maṇimālā recorded (362-364) certain outstanding statements about emerald which 'illumines a place when exposed to the sun; which is not extremely green, yet the splendour of which looks like the lightning's play among fresh grass' (*MM*, 362-363) and lastly 'the sight of which instills the liveliest pleasure into the mind':

यश्च मनस: प्रसादं विदधाति निरीक्षित मतिमां च
तत् मरकतम् महागुणम् इति रत्नविद्यां मनोवृत्ति:
yaśca manasaḥ prasādaṃ vidadhāti nirīkṣita matimāṃ ca
tat marakatam mahāguṇam iti ratnavidyāṃ manovṛttiḥ
(*MM*, 364; also *RP*, 160 and *GP*, 1.71.12-15)

Garuḍa Purāṇa's detailed description of *marakata* gems (*GP*, 1.71.1-29) clearly includes the characteristics of light green *vaidūrya*, bright *marakata* and bluish-green *pannā*, all belonging to the same family.

Perfect emerald gems were known to be rare, and the expression 'an emerald without any flaw' became proverbial. Defective pieces of emerald were sometimes encrusted with *śilājatu* (bitumen), stained and sand-grained (*RP*, 163). *Bhallātaka* and *putrikā* were common imitations, usually lighter, and losing brilliance on exposure and when rubbed (*RP*, 165-167; *GP*, 1.71.20-22). Fake emeralds were known to be softer and to be easily tarnished on application of lime which contrarily brightened real emeralds (*MM*, 382-83).

An emerald 'endowed with virtues' was known to 'fetch more price than a ruby of equal weight'. As a corollary, in case of defects, the depreciation in the value of an emerald had to be more than that of ruby (*RP*, 173-74; *GP*, 1.71.28-29).

Skanda Purāṇa categorised the emeralds as those with quality and those with defects. The emeralds 'with quality' were further subdivided:

गाढं दुर्वादलनिभं श्लक्ष्णं उल्लसितं स्मृतम्
पेशलं कलिमाग्राभं पित्तं शुकगरुत्प्रभम्
मुग्धं तु तुलसी श्यामं पृथकं पद्मपत्रवत्
gāḍhaṃ durvādalanibhaṃ ślakṣṇaṃ ullasītaṃ smṛtam

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peśalaṃ kalimāgrābhaṃ pittaṃ śukagarūtprabham
mugdhaṃ tu tulasī śyāmaṃ pṛthakaṃ padmapatravat
(*SP*, 23.135)

That which resembles the green grass is called *gāḍa*; the pretty small one is called *ullasita*. That similar to the petals on top of a bud is called *peśala*; the one which reflects the feather of a parrot is called *pittam*. The *mugdha* variety is like *tulasī* (leaf) and *pṛthaka* resembles lotus

Skanda Purāṇa referred to the *vaidūrya* (beryl) mines in *Ilāvṛta* and on the Western parts of Mahāmeru. More specifically the mines were said to be located in:

गोरक्षे मागधे देशे पारसीके च सिंहले
मलये च त्रिकुटे च द्वीपान्तर महीषु च
gorakṣe māgadhe deśe pārasīke ca siṁhale
malaye ca trikuṭe ca dvīpāntara mahīṣu ca

Gorakṣa, Magadha country, in Persia, Siṁhala, Malaya and Trikuṭa mountain and in areas in distant islands.

The *vaidūrya* processed and set in jewellery by an expert artisan and that set by an inexperienced artisan naturally differed in containing defects and therefore in prices. (*GP*, 73.14)

TOPAZ (8) PUṢPARĀGA OR PUṢYARĀGA

Kauṭilīya Arthaśāstra (2.11.30) mentioned *puṣyarāga* as a gem, yellow like turmeric. Buddhabhaṭṭa mentioned the same name adding that the gem came from the Himālayas. *Navaratnaparīkṣā* described the gem (*NRP*, 159):

ईषत् पीतम् पविच्छायम् स्वच्छं कान्त्या मनोहरम्
पुष्यरागम् इति ख्यातम् रत्नम् रत्नपरीक्षकैः।।
īṣat pītam pavicchāyam svaccham kāntyā manoharam
puṣyarāgam iti khyātam ratnam ratnaparīkṣkaiḥ ।।

faintly yellow, bright lustre, transparent, excellent appearance.

Maṇimālā quoted passages in which the gem is called *puṣparāga* and compared with *śanapuṣpa* or *śana* flower (*MM*, 392-94; see also *ARP*, 87). *Bṛ. Saṁ.* (80.5) and *GP* (1.74.1) also used the name *puṣparāga*. The latter text namely *GP* also preferred to categorise a large number of yellowish gems, such as those from the ruby-sapphire family, under the category of *puṣparāga* or topaz. Evidently this

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is not scientific.

Pure topaz (hardness eight) is colourless $[Al(F,OH)]_2\ SiO_4$, which could acquire many colours such as blue, red, yellow, etc. Ferrous oxide, lime, alkali, water etc. contribute to the colours. In the Indian context, we are concerned with saffron-yellow 'Indian topaz' which came from Sri Lanka and possibly from the Himālayas as well.

Topaz was found in the former times in Abyssinia and in the same district of Egypt in which emerald occurred, and it is likely that the two minerals were imported together to India. The stone was called in Hebrew *pittdoh*, which was possibly derived from the Sanskrit *pīta* or yellow. The modern name 'topaz' was derived from the Greek *topazion* which meant 'to seek'. An island in the Red Sea, usually covered by mist, was named Topazion and the yellow mineral found in this island was also given the same name. Pliny confused the nomenclature by calling this not-so-hard yellow mineral (actually peridot) as 'topazion' and labelling the actual hard topaz found in Abyssinia and Egypt as chrysolite. Topaz or *puṣparāga* was known in the Muslim period as *pokhrāj*. Yellow corundum and yellow quartz were recognised (through their different values of hardness) as 'false topaz'.

ZIRCON, GARNET AND TOURMALINE

These three gem-minerals were known in the ancient world but were often confused with each other on account of their similar hardness and due to their occurrence in a wide range of colours, often resembling each other (vide Table 7.2).

Zircon (hardness 7-1/2) is the orthosilicate of zirconium, $ZrSiO_4$. Pure zircon is colourless, little iron giving it a colour which is brownish shade of orange, a mixture of red and yellow. Strongly reddish-yellow variety of zircon is known as **hyacinth**; this contains more iron in the ferric form. Pale straw-yellow or colourless zircon known as **jargon** contains iron in the ferrous form. Inter-conversion between hyacinth and jargon is possible by heating under oxidising or reducing atmosphere.

Hyacinth has been often confused with *hessonite* or cinnamon-stone variety of garnet, **Garnet** family of minerals has the general formula $R_3^{2+}R_2^{3+}(SiO_4)_3$ where R^{2+} and R^{3+} could be any bivalent and trivalent metallic cation respectively. Naturally, a wide range of minerals of diverse colour are possible in the garnet family, and actually exist in nature. Hessonite is calcium-aluminium garnet with some replacements by Fe^{2+} and Fe^{3+}. In colour, hessonite resembles cinnamon and the seed of pomegranate or 'grenat' (from which the name 'garnet' has been

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derived). A deeper red variety of garnet, now known as 'almandine', was christened by Pliny as *carbunculus alabandicus* (from Alabanda in Asia Minor) or *carbunculus* (the name was loosely used to represent diverse red stones).

Hessonite and hyacinth are so much alike that lot of hessonite, though inferior in brilliance and luster, were bought and sold in the European market as the coveted hyacinth. Similarly, the lighter variety of zircon or jargon from Matura in Sri Lanka often passed as 'Matura diamond' on account of its transparency, brilliance and high refractive index.

The varieties of zircon can be distinguished from other gems through their remarkably high specific gravity (4.61-4.82) and characteristic hardness 7-1/2 which is slightly more than that of garnet (hardness 7-1/4 and sp. gr. 3.6-3.7) and much less than that of diamond (hardness 10 and sp. gr. 3.52). We have mentioned earlier that the heavier or 'Matura variety of diamond' was considered to be impure or fake diamond (*AM*, 49-52); this came from the gem gravel of Sri Lanka as jargon.

The name zircon came either from *jargon* ('the worthless diamond') or Arabic *zargun* (*zar* — gold and *gun* — colour in Persian). The Indian *Ratnaśāstra* texts referred to light yellow jargon as well as reddish-yellow hyacinth variety of Zircon.

In the pre-Christian era, Kauṭilya mentioned, but did not describe *gomeda* or zircon, excepting bracketting it with *gomūtra* or cow-urine (*AS*, 2.11.30 and 39). *Agastīya Ratnaparīkṣā* made a complete series of descriptive statements about *gomeda* or zircon (*ARP*, 82-86; repeated later in *RRS*, 4.54) :

गोमेद्समरागत्वाद् गोमेद रत्नम् उच्यते
सुस्वच्छम् गोजलच्छायम् स्वच्छम् स्निग्धम् समम् गुरु।
. . . मसृणम् दीप्तम् कबद्ध कान्ति अति स्निग्धम्
धवलम् पिंजरम् पीतकाभम् चतुवर्णम् हि गोमेदम्।।

gomedasamarāgatvād gomeda ratnam ucyate
susvaccham gojalacchāyam svaccham snigdham samam guru ।
. . . . masṛṇam dīptam kabaddha kānti ati snigdham
dhavalam piñjaram pītakābham catuvarṇam hi gomedam ।।

Zircon (*gomeda*) is coloured like cow-flesh (*gomeda*), also like cow-urine. It is transparent, smooth, and very heavy. It may be many-hued (*kabaddha*), white, light yellow or *piñjara* (reddish-yellow, golden, tawny brown); thus, it could have four 'castes' (*caturdhā jātiveda* in *Agastimata* Appendix 4-5 in Finot, p.134).

Navaratnaparīkṣā contains the comparison of zircon with honey and cow-

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urine (*NRP*, 161) :

मधुविन्दुसमम् चापि गोमूत्राज्यसमप्रभम् गोमेदकम्
madhuvindusamam cāpi gomūtrājyasamaprabham gomedakam

Bright golden colour *hemāraktojvalam* of zircon was emphasized in *Laghu Ratnaparīkṣā* (15). *Rayaṇaparikkhā* (*RYP*, 100) compared the colour of zircon with that of *indragopa* or cochineal insect, and mentioned its sources such as the valley of the Narmadā. The other two sources, mentioned as Sirināthakula and Parevaga country, are not identifiable :

श्रीनाथकुल परेवग देशेषु तथा नर्मदानदीमध्ये।
गोमेद इन्द्रगोपः सुस्निग्धः पाण्डुरः पीतः।।
śrīnāthakula parevaga deśeṣu tathā narmadānadīmadhye ।
gomeda indragopaḥ susnigdhaḥ pāṇḍuraḥ pītaḥ ।।

Maṇimālā contained some more statements on *gomeda* (*MM*, 330-337), which was stated to be available in the Himālaya and the shore of the Indus (*MM*, 330). Opinions were divided as to the price of a sterling *gomeda*, 'some maintaining it to be double that of a proportionate mass of gold (evidently zircon in this case was made to pass as diamond), some holding it to be equal to that of a *vidruma* (coral), some to that of *chāmara* (bushy tail of *Bos Granniens*) (*MM*, 336). Fraudulent jewellers were known to fabricate false *gomeda* with crystal, just as transparent or light-coloured zircon or *gomeda* sometimes passed as diamond belonging to one of the four classes or castes (*MM*, 337).

During the middle of the seventeenth century AD, Nicols wrote about the availability of zircon in Cannanor, Calicut and several places in the Kerala sea-coast.

Like zircon, garnet has also been widely available in different localities in India, e.g., Sarwar mine in the Kishangarh district in Rajasthan, Kondapalli in the Godavari district, etc. We are not sure whether the ancient gemmologists of India could distinguish between the hyacinth variety of zircon from the hessonite or almandine variety of garnet, both kinds of material occurring widely in India and Sri Lanka, having similar or overlapping colours and not-too-different values of hardness.

Is Pulaka Garnet ?

The dictionary meaning of *pulaka* is horripilation, and we have explained earlier that this is a fit description of cat's eye gem showing chatoyancy. Kauṭilya mentioned *pulaka* and *śuklapulaka* (*AS*, 2.11.35) which could represent chrysoberyl cat's eye and quartz cat's eye; these were later termed as *laśunaka*

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(garlic). Neither Kauṭilya nor Varāhamihira (*Bṛ. Saṁ.* 80.4) described *pulaka*.

Śukla (white) *pulaka* was certainly not the brownish red garnet. Yet Buddhabhaṭṭa used this name to describe something which could be garnet or a chatoyant cat's eye (*RP*, 242) :

गुन्जान्जन क्षौद्र मृणालवर्ण एते प्रशस्त पुलक प्रतिष्ठितः।
सूत्रैः उपेताः परमाः पवित्रा मांगल्यरूपा बहुरूपचरिताः।।
guñjānjana kṣaudra mṛṇālavarṇa ete praśasta pulaka pratiṣṭhitaḥ ।
sūtraiḥ upetāḥ paramāḥ pavitrā māṅgalyarūpā bahurūpacaritā ।।

Pulaka is of many hues. It could be black and red or black-spotted red like the *guñja* berry, or like honey or stalk of the lotus. It could also appear threaded, striated and auspicious.

Later *Garuḍa Purāṇa* elaborated the two parts of the description given in *RP*, 242. In the first part *guñjāñjana kṣaudra mṛṇālavarṇa* was repeated and additional statements were made *gandharva vahni kadalī sadṛśa avabhāsaḥ* — looks like musk-deer, fire or the plantain tree' and that the gem is available in Dāśārṇa (Dhasāna in Central India), Mekala mountain (source of the Narmadā) and Vāgadava or Bagdad (*GP*, 1.77.2 and *MM*, 430). This description could correspond to garnet.

Garuḍa Purāṇa elaborated the second part : *śaṅkhābja·bhṛṅgārka vicitravarṇāḥ svacchāḥ māṅgalyayuktā citrā pulakā* transparent and like the conch, the lotus, the bee or the sun, threaded or striated (*GP*, 1.77.3 and *MM*, 431). The second description matches more with the transparent and light coloured chrysoberyl or quartz of the cat's eye variety with horripilation or chatoyancy, rather than the dark red coloured garnet. It may be noted that we had referred earlier to the statement in *RYP*, 100 that the Narmadā Valley abounds in *gomeda* or zircon having the colour of *indragopa* or cochineal insect. This could easily pass as *guñjāñjana pulaka* or garnet.

It is quite possible that *pulaka* described in *RP*, 242 and *GP*, 1.77.2-3 corresponds not to garnet but to cat's eye varieties only. Bauer (1968: 492) mentioned that quartz cat's eye deposits of reddish brown colour (resembling garnet) were available in Quilon, Cochin and in several other places of Malabar coast. This variety of quartz cat's eye as well as green chrysoberyl cat's eye were available in Sri Lanka also.

Similar colours of different varieties of gems often confused the ancient gemmologists, who were not equipped with the knowledge of modern science. Pliny for example, tended to call most red gems as **carbunculus**, and then subdivided this family into categories: male and female. The former was ruby,

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and the 'female' carbunculus matched with hyacinth zircon or hessonite garnet. This confusion probabaly existed in ancient India too. Reddish garnet was known probabaly by more than one name. Apart from *pulaka* (which indicated cat's eye also) the other name for garnet was *śikhari*. Tagore (1879: 514-15 in *Maṇimālā*) quoted *āraktakāyaṁ śikhari* and attributed this to reddish or pale-red cinnamon-stone or hessonite variety of garnet.

Another gem mineral which has created some confusion is tourmaline. It is like garnet, a group of isomorphous substances with SiO_4 groups (also B_2O_5 groups) and possessing similar hardness (7-1/4) and same range of colour. The chemical formula has been tentatively suggested as H_9Al_3 $(B.OH)_2$ Si_4O_{19} in which nine atoms of hydrogen are replaceable by variable amounts of Al, Mg, alkalies and colour-inducing Mn, Fe, Cr, etc. Mn induces the darker red shade, Cr^{3+} and Fe^{2+} green colour and so on. Tourmaline can be black, blue, green, red etc. Usually it is vertically striated and has resinous luster. Its specific gravity varies between 2.9 to 3.3. It is birefringent (two refractive indices) and dichroic (appearing differently coloured when viewed along different crystallographic axes).

Ancient India was acquainted with the Sri Lankan tourmaline, of yellowish green colour which resembled chrysolite or peridot of lower hardness (6-1/2), and of brown colour which resembled hyacinth variety of zircon. The name 'tourmaline' arose from Turamali, the place in Sri Lanka which supplied zircon, tourmaline and similar gems to Europe during the beginning of the eighteenth century AD.

We are not certain about the Sanskrit equivalent of tourmaline. Tagore (1879: 514-15) quoted a text: *śvetam harinnīlam atīva dīptam gandharvaratnam khalu vajratulyam* and translated this as tourmaline (*gandharva*) which is white, green or blue and bright like lightning. *Vajratulya* could also mean 'hard and sparkling like diamond'. It may be recalled that in *GP*, 1.77.2 the word *gandharva* appeared along with *pulaka* and garnet. This has been quoted before. On the other hand, the text of *Rasaratnasamuccaya* has equated *vaikrānta* with tourmaline 'which possesses eight edges, eight facets, six angles, which is smooth, heavy and associated with mixed colours or play or colours' *miśrita varṇe yukta vaikrānta* (*RRS*, 2.53). It was said to resemble *vajra* and could cut down or deform the metal: *vikṛntayati lohāni tena vaikrāntaka smṛtaḥ* (*RRS*, 2.60).

Tourmaline of course resembles diamond in lustre and high refractive index, but its hardness (7-1/4) is much less than that of diamond (10). We wonder whether blue sapphire (hardness 9) was misunderstood as blue *vaikrānta* of so-called 'high hardness'. *RRS* (2.65-66) mentioned purification of *vaikrānta* with salty, alkaline and acidic liquids or solutions, and extraction of metal (2.69-71) or

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sattvapātana from *vaikrānta*. In this connection we may recall that Kauṭilya mentioned about a metal *vaikṛntaka* and its ore *vaikṛntaka dhātu*. We discussed the problematic identity of these two materials, and opined in chapter 5, that the ore could be magnetite and the metal iron. Did the authors of *RRS* equate *vaikrānta* or black tourmaline with Kauṭilya's *vaikṛntaka dhātu* or magnetite, and proceed to extract metal (*sattvapātana*) from the former?

QUARTZ (7) FAMILY OF GEM-MINERALS

Quartz is pure silica, SiO_2 and has hardness seven in the Moh's scale; it represents the headship of a family of a very large number of minerals occurring in the earth's crust. Silica occurs in nature either as crystalline quartz in unhydrated form, or as chalcedony sub-group of minerals (hardness 6-1/2) which is hydrated silica SiO_2, nH_2O. In pure forms both these materials are colourless, but trace quantities of specific oxides render specific colours and gem-like qualities to them.

Quartz has been known as 'rock-crystal' when it appears as transparent crystal; this was erroneously believed in the ancient world as 'very hard ice congealed in intense cold'. The Sanskrit name has been *sphaṭika** which was known to occur in the Kāverī Valley, Vindhya mountains, China, Nepal (*RP*, 246; *GP*, 1.79.1), in the Himālayas, Sri Lanka, shores of the Tāpī or Tāptī (*NRP*, 153; *MM*, 435), etc.

Ratnaparīkṣā (*RP*, 247) recognised that *sphaṭika* could be as transparent as *ākāśa* (sky) or *taila* (oil). *Maṇimālā* (*MM*, 443) defined:

आकाशशुद्धम् तैलाख्यम् स्फटिकम्
ākāśaśuddham tailākhyam sphaṭikam

Quartz as transparent as sky, is called *taila* or *tailākhya*.

Rasaratnasamuccaya (*RRS*, 4.92) described:

गंगातोयविन्दुच्छवि विमलतमं निस्तुषं . . .
. . . पाषाणैर्यन्निघृष्टं स्फुटितमपि निजां स्वच्छतां नैव जहयात्
gaṅgātoyavinducchavi vimalatamaṃ nistuṣaṃ . . .

---

* Alfred Master drew attention to the Ṛgvedic (1.62.4,1.121.10,4.50.5 and 8.32.35) word *phaligam* probably meaning crystal. *Sphaṭika* first occurs in a late *Upaniṣad*. The Pāli word continued to be *phalika*. Master suggested that the word had a Dravidian origin.

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...pāṣāṇairyannighṛṣṭaṃ sphuṭitamapi nijāṃ svacchatāṃ naiva jahyāt

The best variety has a shade like a drop of gaṅgā's water, very clear, free from chaff. When rubbed on stone, it may be broken, but never loses its transparency.

The property of light-transparency in quartz has been emphasized in *Rayanparikkhā*: *darpaṇa iva sitam* white as mirror (*RYP*, 95).

Jyotīrasaka (*AS*,2.11.35) and *muktajyotirasa* (*MM*, 441) might have been different names of transparent rock crystal permitting migration of rays. Yāska had mentioned (*Nirukta*, 7.23) that double or plano-convex lens ground from rock-crystal was used to converge rays and to produce fire (Wilhelm Rau, *Brennlinse in alten Indien*, Mainz 1983; also *Vedic Bibliography*, fourth volume item no. 31). When used for such a purpose, rock-crystal was known as a *ravikānta* or *sūryakānta* (*NRP*, 155; *MM*; 437 and *RYP*, 96).

सूर्यांशुस्पर्शमात्रेण वह्निम् वमति तत्क्षणात्
सूर्यकान्ति तद् आख्यातम् स्फटिकम् रत्नकोविदः
sūryāṃśusparśamātreṇa vahnim vamati tatkṣaṇāt
sūryakānti tad ākhyātam sphaṭikam ratnakovidaḥ

MM 441 described the same property, but termed the material as *Muktajyotīrasa*:

अत्यन्त निर्मलं स्वच्छं स्रवतीव जलं शुचि।
ज्योतिर्ज्वालनम् आश्लिष्टं मुक्त ज्योतिरसं द्विज।।
atyanta nirmalaṃ svacchaṃ sravatīva jalaṃ śuci ।
jyotirjvālanam āślisṭaṃ mukta jyotirasaṃ dvija ।।

In translucent or opaque form, quartz was compared with the white portion of the eye, the white lotus or conch-shell, sometimes with its colour slightly altered:

नेत्राब्जम् मृणालशंखधवलम् किंचित् वर्णान्तरान्वितम्
netrābjam mṛṇālaśaṅkhadhavalam kiñcit varṇāntarānvitam
(*RP*, 247; *GP*, 1.79.2; *MM*, 443)

It was recognised that quartz occurs in many forms and colours: *nānārūpam manoharam* (*NRP*, 153), *śuddhasphaṭika garbheṣu rāgānām ekaviṃśati* (*AM*, 324) 'Twenty-one different kinds of colours may appear in the matrix of pure quartz'. The variety from the Vindhya mountains and the shores of the Tāptī had the shade like the leaves of the Aśoka flower and brightness of the seed of the pomegranate: *aśokapallavacchāyam dāḍimibījasannibham* (*NRP*, 157; *MM*, 439) *aśokamadhuvartikam* (*AM*, 322).

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The above variety could have been manganese-containing quartz, usually known as **amethyst**. *Agastimata* described (*AM*, 323) different varieties of quartz: golden-hued, blue, resembling zircon, beryl or emerald etc. Blue-black quartz or *nilagandhika* was known to occur in the ruby mines of Sri Lanka:

सिंहले जायते कृष्णम् आकरे नीलगन्धिके।
पद्मरागभवस्थाने विविधम् स्फटिकम् भवेत।।
siṃhale jāyate kṛṣṇam ākare nīlagandhike ।
padmarāgabhavasthāne vividham sphaṭikam bhavet ।।
(*NRP*, 158; *MM* 440)

Maṇimālā (442) described *brahmamaya* as *brahmasūtramaya*, threaded or full of 'sacred threads'. It could have been *brahmamaṇi* mentioned in *Bṛ. Saṁ.*, 80.5 or chatoyant quartz cat's eye. In the same *śloka* (*MM*, 442), *rājamaya* has been described as the red variety of quartz, or ferruginous jasper or carnelian; this could have been the *rājamaṇi* referred to in *Bṛ. Saṁ.*, 80.4. Blue golden quartz was given the name *rājāvarta* (*MM*, 442); most possibly this was not quartz but blue *lapis lazuli*, bedecked with yellowish pyrite.

Tagore (1879:510-11) quoted the description of *svarṇāṅgī*:

नीलं हरित् रक्तसमानवर्णं निर्दोष चामीकर विन्दुयुक्तं
शोभाभिरामं जनचित्तहारि स्वर्णांगि
nīlaṃ harit raktasamānavarṇaṃ nirdoṣa cāmīkara vinduyukṭaṃ
śobhābhirāmaṃ janacittahāri svarṇāṅgi

and translated this as chrysoprase which is 'blue, green or blood-red, beautifully freckled and spotted with the colour of unalloyed gold or thorn-apple (*cāmīkara*). This could correspond to many coloured quartz, multi-phase jasper or aventurine.

Chrysoprase is known to be a fine-grained moderately translucent quartz having a beautiful apple-green colour. The colour arises due to a small percentage of hydrated nickel silicate. Heating causes dehydration and concomitant decolourisation of the mineral. The leek-green colour could also be due to enclosed fine fibres of actinolite. Bauer (1968:498) wrote that 'some very fine stones come from India, but exactly where they are found does not seem to be known'. On the other hand, the reference to gold (*cāmīkara* and *svarṇāṅgī*) could mean that the material was at least partly citrine quartz of a saffrine yellow colour.

Buddhabhaṭṭa made it clear (*RP*, 248; *MM*, 444) that though many-hued, quartz is not as valuable as other gems (usually harder), unless 'it is refined by a skilful lapidary, when it turns out as a good gem'.

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Is Bhīṣma Quartz or Chalcedony?

Having discussed the group of minerals representing **unhydrated** crystalline silica, named quartz, rock-crystal and *sphaṭika* (in Sanskrit), we may proceed to discuss the other group, namely chalcedony, which is SiO_2, nH_2O **hydrated** silica, having lower hardness (6-1/2) and appearing in many forms and colours. Before we do that, we propose to record the observations on *bhīṣma* in the Sanskrit literature; we are not certain whether *bhīṣma* belongs to the quartz or the chalcedony sub-family. Tagore (1879: 497-501) has equated *bhīṣma* with rock-crystal, whereas Sarma (1984: 70) thinks that 'it is probably some kind of white chalcedony'.

Bhīṣma was said to occur in the Himālayas (*RP,* 231; *GP*, 1.76.1), as well as in Kaliṅga, Magadha and the Malaya region (*MM*, 445). Buddhabhaṭṭa compared this gem with white conch-shell, lotus or lily, Somālaka and diamond (*RP*, 232):

> शुक्लाः शंखाब्जनिभाः सोमालकसन्निभाः वज्रनिभाः भीष्मपाषाणाः
> *śuklāḥ śaṅkhābjanibhāḥ somālakasannibhāḥ vajranibhāḥ bhīṣmapāṣāṇāḥ*

Similar description have been given in *GP*, 1.76.2 and *MM*, 446 with the additional remark that these were *śyonāka sannibhāḥ*: like the *śyoṇāka* (*Oroxylum indicum*) flower which is yellowish white. *RYP*, 99 described the gem as 'pale yellow like the moon in the daytime'. These are lustrous and sometimes similar to a fairly big-sized diamond. These gems were often set in gold and used in necklaces (*GP*, 1.76.3 and *MM*, 447). When worn, the gem was 'supposed to protect the person from all dangers' (*GP*; 1.76, 3-6. *MM*, 447-450). Moss-coloured, cloud-like, dirty and rough samples were disliked. The price of the *bhīṣma* gems was fixed by the experts in accordance with its quality and place of origin (*GP*, 1.76.7-8. *MM*, 451-52).

CHALCEDONY GROUP OF GEMS

Before we narrate the Sanskrit nomenclatures, let us briefly mention the modern scientific definitions of the chalcedony group of minerals. Common **chalcedony** is hydrated silica of faint unifom colour, low hardness (6-1/2), low specific gravity (2.60), somewhat porous and consisting of very thin layers of hydrated and cryptocrystalline silica. When such layers are prominent and concentric or wavy, the material is known as **agate**. When the bands are plain, parallel and alternately light and dark, the variety is called **onyx**.

If the colour of chalcedony is uniformily red, it is called **carnelian**; **sard** is yellowish-red or brown. Yellowish colour is due to hydrated ferric oxide, and the

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red due to dehydrated ferric oxide. Iron-containing light yellow chalcedony, agate or sard, when exposed to sun or heat, loses water from the hydrated ferric oxide, and gets converted into red carnelian. This technique must have been practised in the Indian quarries of agate and carnelian over several millennia.

Uniformly dark green chalcedony is **plasma**, and when spotted with red, it is known as **heliotrope**, or **blood-stone**. Now let us come to the Sanskrit literatures on the subject.

Tagore (1879: 510-11) has quoted a Sanskrit text describing *gandhaśasya* which is 'red dashed with white, white dashed with red or perfectly red' and could be agate-carnelian in different stages of ripening. *Piṇḍa* is reddish, pale-red or green, and is remarkably hard. Tagore added in the foot-note (p. 511) that 'the rich of India make pestles and mortars out of this stone, for pulverising medicinal pills'. The material was most likely agate, which was named during the Muslim period of the Indian history as *akīk*.

Lohitākṣa in *AS*, 2.11.35, *rājamaṇi* in *Bṛ. Saṁ.*, 80.4 and *rājamaya* in *MM*, 442 could have meant ferruginous jasper or carnelian. We have already said that *jyotīrasaka* in *AS*, 2.11.35 and *Bṛ. Saṁ.*, 80.5, and *muktajyotirasa* in *MM*, 441 could mean rock crystal and its ray-focusing lens. An alternative suggestion is that these terms could mean light carnelian or agate, reddening on exposure to the warmth of the sun-rays.

Finot (1896: 55) has equated *rudhirākṣa* (*rudhirākhya* in *Bṛ. Saṁ.*, 80.4) mentioned by Buddhabhaṭṭa with cornaline (French) or carnelian, and we think this correlation is justifiable.

Buddhabhaṭṭa's description is as follows:

नर्मदायाम् . . . चिनादिभूमिषु इन्द्रगोपकनिभम् . . .
प्रकट प्रीलु समान देहम् . . . रुधिराक्षमुख्यम्
narmadāyām . . . cinādibhūmiṣu indragopakanibham . . . .
prakaṭa prīlu samana deham . . . rudhirākṣamukhyam
(*RP*, 243-245)

'*Rudhirākṣa* (red-eyed) gem is available on the Narmadā valley, in China, etc. It is like *indragopa* or cochineal insect (honey-coloured) and *pīlu*, the ripe berry of *salvadora persica* which is said to be dark red. Buddhabhaṭṭa has also alluded to the occasional greenish and bluish shades of *rudhirākṣa*, which we are unable to explain. In *Rayaṇaparikkhā*, Pherū mentioned that in the thirteenth-fourteenth century AD, India was importing from Yemen some low-price *akīk* or carnelian which had the colour of *pīlu* (ripe berry, *Salvadora persica*):

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यमनदेशे अकीकं लघुमूल्यं पीलुसमरंगम्
yamanadeśe akīkaṃ laghumūlyaṃ pīlusamaraṅgam
(*RYP*, 104)

Aqīq or *akīk* is loosely translated as agate, but the material from Yemen is certainly cornelian or carnelian of deep red hue, which belongs to the agate family as we have explained earlier. (Sarma, 1984: 71)

Sard and carnelian have always been popular in the ancient world. The name 'sard' was derived from the Arabic *sered* meaning yellow. 'Carnelian' was derived from *corneus* (raw flesh) or the French *cornaline* (the cornel cherry), which explains the often-used spelling cornelian. Carnelian was extremely popular with the Greeks and used in cameos by the Graeco-Romans. Ben Mansur divided the carnelian into seven classes.

But no country in the ancient world adored carnelian as much as India, which mined, processed, used and exported this gem mineral for three to four millennia since the Pre-Harappan era. India has ever been famous for the quarries of carnelian and agate (from which carnelian is made by simple heating) situated (a) in the neighbourhood of Ratanpur, on the lower Narmadā river, in the (former) state of Rājapipla, (b) in the country north of Rājkoṭ, in the Kāṭhiāwār peninsula, and (c) in the Rājamahal hills in the east where the Ganges bands. The lapidaries in Broach, Cambay, and Jabalpur, using materials of the above areas, such as carnelian, agate, moss-agate, heliotrope or blood-stone, have been world-famous.

There are evidences that the inhabitants of ancient India were familiar with onyx and moss agate. Onyx, as we have explained, is agate with plain and parallel bands, alternately dark and light-coloured. Buddhabhaṭṭa provided an incomplete description of the gem-mineral *śeṣa* (*RP*, 175-178) which occurred with emerald, and was said to be striped white and green alternately. Finot equated *śeṣa* with onyx. *Maṇimālā* provided another name *pālaṅka* for onyx, and a Sanskrit text:

कृष्णं हरिल्लोहित शुभ्ररेखाव्याप्तश्च पालंकम् भंगुरम् तत्
kṛṣṇaṃ harillohita śubhrarekhāvyāptaśca pālaṃkam bhaṅguram tat
Pālaṅka or onyx is brittle and has black, green, red or white lines or bands (Tagore, 1879: 510-11)

Onyx was widely mentioned in the Greek and Hebrew literature, the name coming from a Greek word denoting 'a nail'. A Greek mythological story narrated

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that Cupid, with the sharp point of his arrow, cut the nails of the sleeping Venus, which fell into the Indus, and became metamorphosed into onyx. This story suggests that onyx was widely mined and processed in India, and then exported to Greece and other countries. In fact, the materials onyx and sardonyx were widely used for jewellery purposes, for signet rings and like agate and carnelian, for making cups, vases, sword, handles, etc.

Mocha-stone, also known as dendritic or moss agate is a white or grey chalcedony, showing brown, red or black dendritic markings resembling trees and plants. These have been formed by the percolation of a solution containing iron or manganese through fine cracks of the stone, and the subsequent deposition of the colouring matter originally held in solution. The brown and red markings are caused by oxides of iron, and the black by oxide of manganese. Mocha-stone came from the neighbourhood of Mocha in Arbia, hence the name. *Mocha* could also be a corruption of *moschas* or moss-stone. It has been principally obtained from several places in India such as the Deccan traps, Rājkoṭ, Kāṭhiāwār peninsula, the beds of Godāvarī, Narmadā and Jamunā etc. Tagore (1879: 512-13) has quoted a Sanskrit text which says that 'a gem coloured like moss or onion, and freckled like the branched fibrous root of a tree, is called a *gañja* or mocha-stone:

> शैवाल श्रुद्रप्रिय(पलाण्डु)तुल्यरूपम् गंजम् शिफावत् चिरचिह्नयुक्तं
>
> *śaivāla śrudrapriya(palāṇḍu)tulyarūpam gañjam śiphāvat circihnayuktam*

Plasma is dark leek-green or apple-green chalcedony, the colour arising due to intimate and uniform inclusions of green-earth, a chloritic or micaceous substance in the matrix of hydrated silica. Heliotrope (Greek equivalent of sun-turning) or blood-stone is plasma streaked with fine blood-red spots. A famous sculpture executed in heliotrope, preserved in the National Library at Paris, represents the scourging of Christ, the red marks of the heliotrope representing drops of blood on the raiment. As a matter of fact, there is a post-Christian tradition that Christ's blood fell on dark-green plasma, and thus arose heliotrope.

Plasma and heliotrope were mined extensively from the Indian sources. Plasma occur in the volcanic rocks of the Deccan, specially south of the Bhīma river, as pebbles around the rivers of Kṛṣṇā, Godāvarī etc. Heliotrope has been available in the district north of Rājkoṭ, West of Cambay, around Pune and the Rājmahal hills on the Ganges, along with agate, carnelian and plasma — all these materials having been used in rings, pins, brooches, and similar ornaments.

Tagore (1879: 512-13) has quoted a Sanskrit text in which *jyotīrasa* has been described as a 'dark blue, hard and beautiful gem marked with red (blood) spots':

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ज्योतीरसं मेचकम् अस्रविन्दुव्याप्तं दृढं सुन्दरकान्तियुक्तं

jyotīrasaṃ mecakam asravinduvyāptaṃ dṛḍhaṃ sundara-kāntiyuktaṃ

Mecaka is dark blue (green also?) and *asra* means blood. *Jyotīrasa* in this passage, was rightly equated by Tagore as blood-stone or heliotrope. It should also be noted that *Arthaśāstra* mentioned *jyotīrasaka* (*AS*, 2.11.35) and *Bṛhatsaṁhitā* mentioned *jyotīrasa* (*Bṛ. Saṁ.*, 80.5) without explaining what these materials were, and we have taken the liberty of suggesting that in different contexts these could have meant lens-grade rock crystal or agate-carnelian complex. *Lohitākṣa* and *jyotīrasaka* in *AS*, 2.11.35 could mean either carnelian or heliotrope (as suggested by Tagore).

ON JADE

Actinolite means 'ray' in Greek, and is a typical calcium-magnesium-iron (fibrous) amphibole silicate $Ca_2\,(Mg,Fe)_5\,(OH)_2(Si_4O_{11})_2$. Substitution by aluminium in this structure results in hard and intertwining fibres and a family of gem minerals known as **Jade**. These minerals may have hardness only 6-7, sometimes 5-1/2 in the Moh's scale and yet, on account of the fibrous structure these are exceptionally tough and difficult to fracture.

Nephrite belongs to the amphibole group (double chain in the molecular level) whereas *jadeite* and *chloromelanite* belong to the single chain of pyroxene group. Nephrite may be white or green, due to iron and manganese. Apple-green or emerald green jadeite is so coloured, due to the presence of chromium. Black colour of chloromelanite is due to excess concentration of iron in the structure.

Nephrite quarries in the Central Asia, in the Kuen-Lun mountains, Nan-Shan mountains in China etc. have been widely known. There is some nephrite in the southern part of the Mirzapur district in India. Good reserves of chloromelanite and jadeite (*yu* in Chinese) occur in the sub-division of Mogoung in Upper Burma.

The jade materials have been very popular in China and Central Asia, and extensively used to make a wide range of plates, bowls, vases, sword-handles and idols.

A large number of Buddha images have been made out of jade, and in this connection use of jade became popular in India. Tagore quoted (1879: 512-13) a Sanskrit text describing *pīlu* or jade as 'smoke-coloured, white or green shaded with white, and hard, non-transparent and slightly lustrous':

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धूम्रं सितं श्वेतहरित् कठोरम् अस्वच्छम् अल्पाभमतीव पीलु
dhūmraṃ sitaṃ śvetaharit kaṭhoram asvaccham alpābhamatīva pīlu

During the Muslim period of Indian history, jade was known not only as *pīlu* but also as *yasam* and *jaharmuhrā*. We have indicated earlier that *pīlu* stood for agate-carnelian also.

FELDSPAR GROUP OF GEMS

$RAlSi_3O_8$ represents the general group of feldspar minerals where R may be potassium (partly replaced by sodium) in orthoclase and microcline, or sodium (partly replaced by calcium) in plagioclase.

Moonstone, available in Sri Lanka, is a microperthitic to sub-microperthitic intergrowth of orthoclase and albite in an arrangement of thin layers exhibiting a pearly opalescent reflection or shiller or a delicate play of colours. It has a beautiful blue bloom and lovely sheen. **Sunstone** is a variety of oligoclase, Na-Ca feldspar containing little K and Ba feldspar. A play of colour (fire-red, yellow, blue, green etc.) is a common characteristic of sunstone; this is due to interference of light, caused by reflection from thin lamellar inclusions of various minerals such as hematite, goethite etc. Usually this mineral is associated with igneous rock.

Nandaka and *śītavṛṣṭi* in *AS*, 2.11.31-32 could have been moonstone, which was mentioned as *śaśikānta* in *Bṛhatsaṁhitā* (*Bṛ. Saṁ.*, 80.4) and *Rayaṇaparikkhā* (*RYP*, 96), and as *candrakānta* in other texts such as *Navaratnaparīkṣā* (*NRP*, 154 and 156), *Ratnasaṁgraha* (*RS*, 18) and *Maṇimālā* (*MM*, 436 and 438). The typical description of *candrakānta* is:

पूर्णेन्दुकरसंस्पर्शात् अमृतं क्षरति क्षणात्।
चन्द्रकान्ति तत् आख्यातम् दुर्लभम् स्यात् कलौ युगे।।
pūrṇendukarasaṃsparśāt amṛtaṃ kṣarati kṣaṇāt ।
candrakānti tat ākhyātam durlabham syāt kalau yuge ।।
(*NRP*, 156; *MM*, 438)

That which runs nectar when the moon at its full bathes it with its balmy influence, is called *candrakānta*.

Sanskrit literature is replete with '*candrakānta* slabs on which lovers in separation seek solace'. Could these be plain marble?

The *Ratnaśāstra* texts (*NRP*, 154 & 156; *RS*, 18; *MM*, 436 & 438; *RYP*, 96) claim that *candrakānta* is a variety of *sphaṭika* or quartz. But we believe that

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candrakānta is a moonstone, a variety of feldspar defined earlier, which was available in Sri Lanka only. As it stands admitted in *NRP*, 156 (*durlabham*), it was rarely availble in India.

Sūryakānta or *Ravikānta* (*AS*, 2.11.32; *NRP*, 154-155; *RS*, 18; *MM*, 436-437 and *RYP*, 96) could however belong to the quartz family as claimed in the above-cited literatures. We have earlier quoted *NRP*, 155: *sūryāṃśusparśamātreṇa vahnim vamati* which means 'fire emerges when sun-rays pass through', and implies that *sūryakānta* could mean a lens of tranparent rock crystal. Alternatively, it could be sunstone of the feldspar family as defined earlier.

Hiuen Tsang (AD 629) mentioned about *Yun-shih* rock near the *Tilaḍaka* monastery in Magadha. It has been translated as cloud-stone or 'variegated marble' (Samuel Beal: *Buddhist Records of the Western World*, 1969, Book VIII, p. 103). It could be a siliceous rock as well.

We may briefly comment on fine **yellowish-green** or golden yellow **chrysolite** (French jewellers call it *peridot*), which is precious olivine or a gem variety of the group of mineral called olivine $R_1^{2+} R_2^{2+} (SiO_4)$ wherein R_1 and R_2 could be various combinations of Mg, Fe, Ca and Mn. Chrysolite contains more of Mg and Fe^{2+} accounting for the typical colour. Its hardness is 6-3/4; it is slightly softer than quartz and its specific gravity is 3.33-3.37, more than that of emerald. At present, the reserves of the gem probably stand exhausted, but in the ancient world, it was well-known and created some confusion with emerald (green) and topaz (yellow), all the three gem minerals occurring together between the Nile and the Red Sea. E.S. Dana has commented that 'the *chrysolithus* of Pliny was probably our topaz and his **topaz** our chrysolite'. The two different materials could be easily distinguished in terms of their hardness, topaz being much harder.

The above confusion between chrysolite and topaz was connected with the Sanskrit words: *pīta* meaning yellow and *pittaka* meaning colour of bile what is green or greenish-yellow. *Arthaśāstra* mentioned a gem *pittaka* (*AS*, 2.11.35) which was most possibly chrysolite. Later, another name came up: '*rucaka* which is yellow, green, red or tawny, found in the borders of Kashmir' (quoted by Tagore in *Maṇimālā*, pp. 508-9), and this also could be chrysolite. The Sanskrit word *pīta* was converted to *pittdoh* in Hebrew and then to *tipdoh* and *topazion*. The confusion between *pittaka* chrysolite and *pīta* topaz is now a matter of history.

TWO SOFTER BLUE GEMS OF THE ANCIENT WORLD

Turquoise (hardness 6) and *Lapis Lazuli* (5-1/2) are famous as two relatively soft blue gems. These were widely used in the ancient world, which had not yet

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invented the techniques to cut and process the harder gems such as blue sapphire (9).

Turquoise is a hydrous phosphate of aluminium and copper. It may be considered to be an aggregate of orthophosphoric acid molecules hooked with (CuOH) and $Al(OH)_2$ radicals, the tentative formula being $H_5(CuOH)[Al(OH)_2]_6(PO_4)_4$. The sky blue, dark blue or bluish colour is due to copper.

In the Harappan period, much of the supply of turquoise came from Persia, near Niśāpur in Khorasan. The turquoise mines over there, existing in rocks consisting of porphyritic trachytes, are of great antiquity. The material was always in demand in India and imported, unless for some reason or other, the trade links were snapped. Finot has quoted (1896:138) *Agastimata* Appendix 38 and *Ratnasaṁgraha*, 20 (Finot, p. 197) which provide the same description indicating the blue and yellow colour of *pīroja/perojā* or turquoise. The latter references (*RS*, 20) mentioned that the gem could be *mecaka* or dark blue. Pherū wrote in *Rayaṇaparikkhā* about the gems from Persia imported to India in the thirteenth-fourteenth centuries AD: *pārasika ratnāni* (*RYP*, 103). These were spinel (*lāl*), carnelian (*akīk*) and turquoise (*perujjā* or *perojā*). He wrote that blue and clear turquoise occurs in the mines of Niśapur (Nīsāvara) and Al-Moussul (Muvāsīra), and that this is beneficial to the eyes (*RYP*, 105):

नील अमलं पेरोजं देशे नीसावरे मुवासीरे उत्पद्यते खनिभ्य:

nīlaṃ amalaṃ perojaṃ deśe nīsāvare muvāsīre utpadyate khanibhyaḥ

The earlier literatures had also mentioned that turquoise is good for the eyes. The *Ratnasaṁgraha* had mentioned in addition that turquoise is *viṣanāśanam* an antidote to poison (*RS*, 20).

The turquoise of Niśāpur was considered to be as precious as ruby and sapphire of Sri Lanka and the emerald of Egypt. The name turquoise is the French word for Turkish; the mineral travelled to the West from Persia through Turkey. Tagore (1879: 386-87) quoted a Sanskrit text saying that emerald comes from the sea-coast of Turuṣka (translated as Turkey). The name *tārkṣya* (in *RRS*, 4.5-4.6) has been translated as emerald. Possibly there was a confusion between blue turquoise and bluish green emerald. The word *turuṣka* (used in *AM*, 287 and *GP*, 1.71.4 in connection with the source of emerald) means storax or a balsam obtained from the foreign tree of *Ligendamber*.

It is surprising that in *Rayaṇaparikkhā*, Ṭhakkura Pherū mentioned turquoise but not the other famous blue gem, *lapis lazuli* which used to be imported to India over centuries since the Harappan era. *Lapis lazuli* (hardness 5-1/2), the richly coloured blue material is a heterogeneous mixture of several minerals:

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lazurite	$3Na_2Al_2Si_2O_8$, $2Na_2S$ (chief ingredient)
alternatively	$(Ca, Na)_8(Al,Si)_{12}O_{24}(S, SO_4, Cl)_x$ (polysulphide units)
haüynite	$3Na_2\ Al_2Si_2O_8$, $2CaSO_4$
sodalite	$3Na_2\ Al_2Si_2O_8$, $2NaCl$

It has been conclusively proven that the deep blue colour of lazuirite is due to the transition among the orbitals of the 19 outer electrons of the S_3^- polysulphide units in the mineral. (Nassau, 1983: 149) Pale blue samples when raised to a dull red-heat, assume fine dark blue colour possibly because a larger proportion of sulphur atoms re-align themselves to form S_3^- ions as in artificial ultramarine.

The largest known *lapis lazuli* mines are situated in Badakshan in the north-east corner of Afghanistan, in the upper part of the valley of the Kokcha, a tributary on the left bank of the Oxus (36-1/2°N latitude and 70-1/2°E longitude). The anicent mining method involved putting up big fires in the mine, soaking the heated rocks with water and then hammering the loosened and cracked pieces of blue rock.

Lapis lazuli has been used to make small articles such as bowls, vases, fancy articles of various kinds. The blue colour is often flecked with shining, metallic specks of iron pyrites; Pliny compared such stones with the star-bedecked blue sky. *Maṇimālā* (*MM*, 442) described such a sample, as a blue mass flecked with gold: *ānīlaṃ svarṇayukta yat tu rājavartaṃ udāhṛtam*.

The name *Lapis Lazuli* was most possibly derived from the Persian *lazhward*, meaning blue colour. In some Sanskrit text, this name was retained:

> लाजवर्तः अल्पशः रक्तः नीलिमामिश्रित प्रभः
> *lājavartaḥ alpaśaḥ raktaḥ nīlimāmiśrita prabhaḥ*
> *Lājavarta* is coloured blue slightly reddish. (*Agastīyā Ratnaparīkṣā*, 93).

In another text, it was mentioned as *rājāvarta*:

> निर्गौरम् असितम् स्वच्छम् नीलस्वच्छम् समं गुरु
> शिखिकण्ठदृढ़म् शुद्धम् राजावर्ते गुणा दश
> *nirgauram asitam svaccham nīlasvaccham samaṃ guru*
> *śikhikaṇṭhadṛḍham śuddham rājāvarte guṇā daśa*
>
> *Rājāvarta* is not white (distinguished from white calcite which may be associated with it — author but blue or dark blue like the neck of a peacock. (*Laghu-Ratnaparīkṣā*, 19)

Rasaratnasamuccaya (*RRS*) mentioned in its chapter four, that *rājāvarta* has a

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mixed shade of blue and slight reddish colour, and that it is heavy and smooth. All the Sanskrit texts referring to *lapis lazuli* mention that it is *guru* or heavy. Its specific gravity however is actually low (~2.4), much lower than that of blue sapphire (~ 4.1) and on this point, the ancient scholars might have confused one kind with another. *RRS* further mentioned *satvapātana* or metal extraction from *rājāvarta*. We wonder what metal was extracted from this gem. Possibly the author of *RRS* confused *sasyaka*, a blue copper mineral, from which copper metal was extracted (*RRS*, 2.125-133), with *rājāvarta*.

Before we pass on to coral and pearl, the softest gem minerals, we may briefly mention a few minor gem minerals such as *vimalaka* or the gem variety of pyrite. Pyrite FeS_2 has metallic lustre, specific gravity 5.0 and hardness 6-1/2. It is pale brass yellow, and occurs in striated cubic and pyritohedral (fourteen surfaces) forms. On account of its brilliant lustre and pretty colour, it was much esteemed and used in brooches, bracelets, as recently as in the eighteenth century, specially in France, till its use was given up. It was mentioned as *vimalaka* in *Arthaśāstra* (*AS*, 2.11.35, and *Bṛhatsaṁhitā* (*Bṛ. Saṁ.*, 80.4).

Rasaratnasamuccaya (*RRS*) mentioned *vimala* or pyrite occurring in several kinds: *tāra vimala* (silver-like iron pyrite or *vimalaka*), *hema vimala* (golden chalcopyrite) and *kāṁsya vimala* or arsenopyrite (*RRS*, 2.95). These were mentioned as *rasas* or ores from which metal could be extracted. Only the first one, namely *tāra vimala* or iron pyrite had been used as a minor gem in India and that too well before the thirteenth century AD.

Sasyaka or blue copper mineral (covellite, bornite or copper sulphate crystal?) was mentioned as a minor gem (*AS*, 2.11.35 and *Bṛ. Saṁ.*, 80.5) in the early centuries, but not counted as a gem during the later years. Similarly *añjanamūlaka*, the pigment grade dark blue mineral (carrolite, a cobalt compound? or an antimony compound?) was mentioned in *AS*, 2.11.35, but must have lost its reputation as a gem in the post-Christian era. Conch or *śaṅkha* had been widely used in India throughout the ages, even in Pre-Harappan times. *Bṛ. Saṁ.*, 80.4 mentioned this as a gem, but not other gemmologist mentioned it, although the material has always been used for other purposes, such as making bangles.

A very striking fact is that *Arthaśāstra*, otherwise more or less complete in its list of gems, does not mention *marakata* or emerald which became very popular in the sub-continent during the post-Christian era. This also proves the antiquity of the said text, which is probably the oldest to provide a list of gem-minerals used in India.

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CORAL, PRAVĀLA OR VIDRUMA

Calcite is one of the softest minerals known. Its hardness is three in the Moh's scale. The corresponding rocks: limestone and (metamorphosed) marble or *marmara* (in Sanskrit) have been used for various constructional purposes but never as gems. Coral and pearl, organic in origin and largely calcitic in nature, have however been widely used as gems, on account of their beautiful colour and lustre, even though their hardness is slightly below four in the Moh's scale.

Red or precious coral constitutes the substance of the calcareous axial skeleton of the coral polyp, *Corallium rubrum*, a lowly organised animal belonging to the class Anthozoa. Branching colonies growing on the sea-floor (30 to 300 meters below the sea-level) are supported by axial rods of red calcareous material, the so-called coral, invested by a layer of soft, living material known to zoologists as the **coenosarc**. The cells of the coenosarc have the power of separating out calcium carbonate from the sea water and adding on to the axial skeleton of coral.

The approximate composition of red coral (in percentage values) is: $CaCO_3$ 87.0, $MgCO_3$ 6.8, $CaSO_4$ 1.3, Fe_2O_3 1.7, Organic matter 1.35, water 0.6, and the rest, phosphate, silica, etc. 1.3. The exact composition varies with the age of the coral and other factors. With advancement in age, the coral hardens and assays higher in the percetage of $MgCO_3$. The amount of organic matter, which is the principal cause of colour, is much higher in black coral (above 3 per cent), which cobtains less iron (0.8 per cent). The colouring constituent is decomposed on heat, and this could be an organic compound with iron complexed in it.

Some coral-fishing might have been done in the past in the Indian ocean, the Persian Sea and the Red Sea, but the principal source of the gem variety of red coral has always been the Mediterranean Sea. The Indians have always preferred this variety instead of the yellowish white materials in the Persian Gulf.

Kauṭilya gave the first description of coral:

प्रवालकम् आलकन्दकं वैवर्णिकं च
रक्तं पद्मरागं च करट गर्भिणिका वर्जम् इति
pravālakam ālakandakaṃ vaivarṇikaṃ ca
raktaṃ pdmarāgaṃ ca karaṭa garbhinikā varjam iti
(*AS*, 2.11.42)

The coral from Alakanda (Alexandria?) and from *Vivarṇa*, red and of the colour of the lotus (is excellent), with the exception of that which is eaten by insects and what is bulging in the middle.

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Pravāla is mentioned in *Bṛ. Saṁ.*, 80.5 also. *Navaratnaparīkṣā* described how coral or *vidruma* grows like tree under the water level (*NRP*, 162):

सरिताम् पतिमध्ये तु जायते वल्लरी तु या
विद्रुमाख्या सुरक्ता सा दुर्लभा रत्नरुपिणी
saritām patimadhye tu jāyate vallarī tu yā
vidrumākhyā suraktā sā durlabhā ratnarūpiṇī

Maṇimālā (*MM*, 338) provided a similar text: '*Vidruma* is a cross-shaped gem resembling a plant (*vallarī*) and found in the White Sea'.

Buddhabhaṭṭa gave a detailed description of coral and its origin in the sea around Rome (*RP*, 249-252):

तत्र प्रधानम् शशलोहिताभं गुंजाजवापुष्पनिभम् प्रशस्तम्
संलाशकम् देवक रोमके च स्थानानि येषु प्रथितम् सुरागम्
अन्यत्र जातम् च न तत् प्रधानम् . . .
प्रसन्नम् कोमलं स्निग्धं सुरागं विद्रुमम् हितम्
धनधान्यकरं लोके स्त्रीणाम् सौभाग्यदायकम्
दुष्टव्याधिहरम् चैव विषादिभयनाशनम्
tatra pradhānam śaśalohitābhaṃ guñjājavāpuṣpanibham praśastam
saṁlāśakam devaka romake ca sthānāni yeṣu prathitam surāgam
anyatra jātam ca na tat pradhānam . . .
prasannam komalaṃ snigdhaṃ surāgaṃ vidrumam hitam
dhanadhānyakaraṃ loke strīṇām saubhāgyadāyakam
duṣṭavyādhiharam caiva viṣādibhayanāśanam

The most important (variety of coral) is the one coloured like the blood of a hare, the *guñja*-berry or the China-rose. It is available in *saṁlāśa* (Sunīlaka in *GP*, 1.80.2), Devaka and Romaka (Rome). Corals found elsewhere are not so important. . . Corals of pleasing colour, soft and glossy, possessing deep crimson colour are productive of wealth and food-grain, bring good luck to the women and dispel the fears of disease, poison, etc.

Garuḍa Purāṇa copied the above text of *Ratnaparīkṣā* almost verbatim (as in many other cases) and added that some coral was available in Kerala (*GP*, 1.80.1); presumably the coral in Kerala did not belong to good variety. As in *Ratnaparīkṣā* (*RP*, 250), *Agastimata*, Appendix 10 (quoted by Finot, p. 135) also mentioned that the best coral was obtained from the sea-coast of a foreign land:

म्लेच्छभूदिशि पर्वते लवणः सागरो तत्र प्रवालोत्पत्ति

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mlecchabhūdiśi parvate lavaṇaḥ sāgaro tatra pravālotpatti

In *Agastīyā Ratnaparīkṣā* we find another description of coral:

गुंजा बन्धूक सिन्दूर दाड़िमीकुसुमप्रभम्
guñjā bandhūka sindūra dāḍimīkusumaprabham
(*ARP*, 94)

that which resembles *guñjā* berry, the *bandhuli* flower, the vermilion or the pomegranate flower'.

also straight and circular or cylindrical (*ARP*, 95) : *vṛttāyatam avakrakam.*

The Sanskrit extracts on coral provided in *Maṇimālā* (*MM*, 338-344) show that in India corals of different shades of colour were held to belong to different castes: the brāhmaṇa variety is crimson-red, like the blood or eye of the hare, easily penetrable and delightful (*MM*, 340):

अरुणं शशरक्ताक्षं . . . सुखवेध्यं मनोहरम्
aruṇaṃ śaśaraktākṣaṃ . . . . sukhavedhyaṃ manoharam

That which resembles *javā* or China-rose or vermilion and is very hard, belongs to the kṣatriya family. Pale coloured and poor lustre samples belong to the two lower castes (*MM*, 341-344). Roughness and the quality of being discoloured or disfigured with lines and spots etc. rendered coral as unacceptable (*MM*, 346-347).

Coral beads have been used by the religious people of India as rosaries to count their prayers. It has been worn in form of necklaces, bracelets, anklets, and other ornaments.

Pliny had observed (32.11) with some surprise that red coral, which was not so much in demand in the Roman Empire, was as highly prized in India as the white pearl at Rome. V. Ball, the famous nineteenth century mineralogist, ascribed the Indians' preferance for red coral to 'the way its tints adapt themselves to set off a dark skin, and also look well with a white garment'. Black coral, in abundance in the Red Sea, was not so popular in India.

PEARL OR MUKTĀ

There are many kinds of pearl-like substances in nature, but we are concerned mainly with the pearl produced by the molluscs or oysters *Meleagrina margaritifera* (fresh water species). The pearl is the response of the mollusc to the stimulus afforded by a local irritation of the mantle. A small foreign body acts as the nucleus, and the concentric material deposited on it are alternate layers

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of calcium carbonate (as aragonite) and the protein conchiolin both produced and secreted internally by the organism; this is also the constitution of the inner coating of the shells known as the 'mother of pearl'.

Thin alternate laminated layers of aragonite and conchiolin result in the gem of various sizes, specific gravity 2.65-2.68 and hardness around four in the Moh's scale. Light penetrates the first few translucent layers and then get reflected; the combined reflection causes the play of colour and what we know as 'pearly lustre'. Thinner the calcareous laminae, the more beautiful is the lustre. The pearls produced by the marine molluscs are far superior to those produced by the fresh water species.

In terms of hardness, diamond (10) and pearl (4) are poles apart. On account of the high content of organic material (nearly 10-12 per cent of conchiolin), pearl gradually decays and becomes brittle after a long time. Yet, its beautiful lustre has made it as popular as diamond. On the beauty, popularity and worth of the lustrous pearl, Buddhabhaṭṭa wrote eloquently, and his composition (*RP*, 69) was repeatedly quoted later by other authors:

> विचित्ररत्नद्युति चारुतोय चतुःसमुद्राभरणाभिरामा
> मूल्यम् न वा स्यात् इति निश्चयो मे
> कृत्स्ना मही तस्य सुवर्णपूर्णा
> *vicitraratnadyuti cārutoya catuḥsamudrābharaṇābhirāmā*
> *mūlyam na vā syāt iti niścayo me*
> *kṛtsnā mahī tasya suvarṇapūrṇā*
>
> (*RP*, 69; *GP* 1.69.17)

> I am sure that the whole earth surrounded by four oceans, overflowing with waters sparkling like gems, is not an adequate price for this (pearl), even if this earth is filled with gold.

Before we quote references on the beautiful oyster-pearl, let us mention the **other kinds** of pearls which have received minor attention in the Sanskrit literature.

Buddhabhaṭṭa wrote about different kinds of pearls:

> Pearls are found in lordly elephants, clouds, wild boars, shells, fishes, cobras, oysters and the bamboos. Pearls in oysters are more abundant. (*RP*, 52)

Some details were given in *Ratnaparīkṣā*, 53-68, and the entire material was reproduced almost verbatim in *Garuḍa Purāṇa*, 1.69.1-16. Similar lists have

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been provided in *AM*, 83-106; *NRP*, 60-68; *MM*, 243-258, 261 & 265, *RS*, 6 and in *RYP*, 39-48.

It is a common misconception that pearls are produced only by the pearl oysters and the other seven types are imaginary. In this regard, Sarma (1984: 54-56) has put the record straight. The cloud pearl is of course mythical, but other kinds are not fictitious though rare.

The common conch-shell (*Strombus gigas*) or large conch (*Cassis corunta*) produce pearls of ornamental value, and these are called conch pearls or pink pearls (Herbert Smith, *Gemstones*, p. 472). These pearls are pink or white, non-nacreous, and have porcelain-like surface with a peculiar appearance and sheen like watered silk (Robert Webster, *Gems*, London 1962, Vol. 1, p. 387).

Conch-pearl has been probably the gem, earliest recorded in the Indian literature. In the *Ṛgveda* and in the subsequent Vedic literatures, *śaṅkha* (conch) and *kṛśan* (conch-pearl) were mentioned together (vide chapters 2 and 3). Kauṭilya recognised that oysters as well as conch-shells were the sources of pearls (*AS*, 2.11.3). Buddhabhaṭṭa (*RP*, 57) and *Garuḍa Purāṇa* (1.69.6) mentioned that conch-pearl is yellow. Varāhamihira wrote (*Bṛ. Saṁ.*, 81.28):

> शंखोद्भवं शशिनिभं वृत्तं भ्राजिष्णु रुधिरं च
> *śaṅkhodbhavaṃ śaśinibhaṃ vṛttaṃ bhrājiṣṇu rudhiraṃ ca*
>
> The pearl born of conch-shell is round, lustrous, beautiful and moon-like.

In *Navaratnaparīkṣā* (67 & 82), conch-pearl was specifically mentioned as *kṛśan* since it was longish, like the egg of a pigeon, coming from *Pāñcajanya* (the famous name of conch) and lustrous like hail-stone:

> दीर्घम् च यत् कृशम् प्रोक्तम् कपोताण्ड प्रमाणम्
> वर्षोपल समदीप्ति पान्चजन्य कुलोद्भवम्
> *dīrgham ca yat kṛśam proktam kapotāṇḍa pramāṇam*
> *varṣopala samadīpti pāñcajanya kulodbhavam*

Pherū wrote (*RYP*, 41) that conch-pearl with a reddish tint occurs in the right-whorled conch (*dakṣiṇāvarta saṅkha*). *Maṇimālā* (266-270) provided some collected information:

> Only the yellow-bodied and black-mouthed conch-shells produce pearls. Such a pearl has the dimension of a large plum, and is white as the inner surface of the coat of that shell fish. There are twenty-seven kinds of conch-shells, produced by as many stellar

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constellations. A conch-pearl could be white, black, yellowish, crimson blue, reddish, deep yellow, ash-coloured or pale red.

The bamboo pearl is also quite real; some female bamboos produce a siliceous concretion in their joints which is called in Sanskrit *vaṁśamuktā*, *vaṁśalocana*, *vaṁśakarpūra*, *tvakṣāra*, *tvakṣīra* (Persian *tabāshir*), etc. The Indians, Persians and Arabs were aware of its medicinal properties. (Edward Balfour, *Encyclopaedia Asiatica*, New Delhi, 1976 volume 8, p. 797).

Varāhamihira wrote (*Bṛ. Saṁ.*, 81.28) that 'a pearl is to be known to have sprung from bamboo, if it resembles camphor or rock crystal and is flat and uneven (or rough)':

कर्पूरस्फटिकनिभं चिपिटं विषमं च वेणुजं ज्ञेयम्
karpūrasphaṭikanibhaṃ cipiṭaṃ viṣamaṃ ca veṇujam jñeyam

The bamboo-pearl has been described as *tvakṣāra* or the essence of the plant-epidermis, *varṣopalasamadiptiḥ*, lustrous like the hailstone, clear as the moon, resembling the fruits of *badari* and *kaṅkolī* or *kakkol*, a fragrant fruit, and the seeds of *guñjā*, *Abrus precatorius*, etc. (*RP*, 61; *AM*, 100; *NRP*, 66; *GP*, 1.69.9; *RYP*, 43). *Maṇimālā* (296) commented that there are five species of bamboos, which produce five different kinds of bamboo-pearls.

Gajamuktā or elephant-pearl, often described in the Sanskrit literature, is a pearl-shaped growth found in the elephants' forehead. In *Navaratnaparīkṣā* (*NRP*, 62; also *MM*, 252), it is mentioned that this kind of pearl 'originates in the head of the elephants of Kāmboja (Cambodia) and is as large as the fruit of the *Emblic myrobalan*, heavy and more yellow, but not more lustrous than the other kinds':

काम्बोजकुम्भिसम्भूतम् धात्रीफलनिभम् समम्।
आताम्रपिंजरच्छायम् मौक्तिकं मन्ददीधिति।।
kāmbojakumbhisambhūtam dhātrīphalanibham samam ।
ātāmrapiṅjaracchāyam mauktikaṃ mandadīdhiti ।।

The yellow colour of the elephant-pearl is mentioned in other literatures also (*RP*, 56; and *GP*, 1.69.5). Pherū compared the size of elephant-pearl with the fruit of *āmalaka* or myrobalan and described that the best kind of elephant-pearl has yellowish-red colour but dull lustre (*RYP*, 40).

The boar-pearl could also be an outgrowth or antidotal concretion developed in the body of the boar, somewhat akin to the bezoar stone. Varāhamihira wrote:

दंष्ट्रामूले शशिकान्ति सप्रभं बहुगुणं च वाराहम्।
daṃṣṭrāmūle śaśikānti sapraphaṃ bahuguṇaṃ ca vārāham ।
(*Bṛ. Saṁ.*, 81.23)

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Very valuable and lustrous like the moon is the pearl born of the root of the boar's tusks.

Maṇimālā (261 & 265) described it as generally white like the tusks of that animal, and resembling a plum in shape. Pherū wrote that the boar-pearl is round, *ghī*-coloured and equal in size to *sālaphala*, the fruit of *Shorea robusta* (*RYP* 44).

Maṇimālā contains extracts from the Sanskrit literature saying (*MM*, 272-276) that pearls occurring in sea-fish are singularly round, small, light and in colour like the back of the sheat fish, *Silurus Boalis*. The pearls originating in whales are *guñjā*-shaped and *pāṭalī* coloured (*AM*, 90-91).

The earlier writers (*RP*, 58; *Bṛ. Saṁ.*, 81.23; *AM*, 90; *ML*, 2.4.431) specifically mentioned *timija* or the pearl from whales. Sarma (1984: 56) has suggested that this is *ambara* or ambergis which 'consists of the faeces of the Cachelot or Sperm Whale, *Physeter macrocephalus*, which inhabits the Indian ocean'.

Maṇimālā compiled the Sanskrit texts on serpent-pearls (*MM*, 277-284) 'which adorn the serpent's crest, are finely round and highly shining and reflect a beautiful blue halo like the flash of a polished sword' (*RP*, 62; *AM*, 92-93). Varāhamihira admitted that many of the uncommon varieties of pearl, as mentioned above, are rarely seen, and qualified many of his descriptions with the word *kila* denoting 'it is said'. (*Bṛ. Saṁ.*, 81.21)

The Oyster Pearl

Now let us return to the well-known and the best variety of pearl: *śukti muktā* or the pearl from the oyster. We have earlier presented the modern scientific knowledge about oyster-pearl and the description of its 'superlative worth' given by Buddhabhaṭṭa (*RP*, 69 and *GP*, 1.69.17).

The chief sources of the oyster-pearl were mentioned in all the ancient Sanskrit texts; Kauṭilya (*AS*, 2.11.2) named *Pāṇḍyakavāṭaka*, *Pāśikā* in Pāṇḍya country, *Kauleya* in Sri Lanka, *Cūṛni* in Kerala, etc. Varāhmihira referred (*Bṛ. Saṁ.*, 81.2) to eight sources:

Pāṇḍyavāṭaka (Ramnad and Tuticorin area), *Paraloka* (Purali in Travancore coast), *Siṁhalaka* (Sri Lanka), *Saurāṣṭra* (Kāṭhiāwāḍ), Tāmraparṇī and Kāverī river in the Pāṇḍya country, *Pāraśava* (Persia) and the Himālayas (?). *Ratnaprīkṣā* (*RP*, 75-76) and *Garuḍa Purāṇa* (*GP*, 1.69.23-24) provided a similar list of the sources, *Agastimata* (*AM*, 109) mentioned *Barbara* which was probably the African coast of the Red Sea.

Megasthenes (fourth century BC) mentioned large pearls of Sri Lanka and

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Taprobane, a corruption of Tāmraparṇī, the river in the Tinnevelly region in the southernmost part of India. Pliny and the author of the *Periplus* (first century AD), and later, Fa-hien, the Chinese pilgrim (AD 399-414), described the pearl fisheries in South India and Sri Lanka. In *Raghuvaṁśa* (4.50), Kālidāsa wrote about the pearls from the marine estuary of the Tāmraparṇī:

> ताम्रपर्णी समेतस्य मुक्तासारं महोदधेः
> *tāmraparṇī sametasya muktāsāraṃ mahodadheḥ*

Centuries later, Pherū (*RYP*, 49) provided additional names of places as the sources of pearl:

> रामावलोके बबरे सिंहले पारसीके केसियदेशेषु च
> *rāmāvaloke barbare siṃhale pārasīke kesiyadeśeṣu ca*

Rāmāvaloka or Rāmāvaloa was probably Rameshwaran where pearl-fishing was witnessed since the days of Ptolemy. The activities were centred around a chayl or coil, literally the temple on the sandy promontory of Ramnad (Balfour, *Encyclopaedia Asiatica*, Vol.7, p. 168). Kesiya was probably the island of Qays in the mouth of the Persian gulf. Barbara, as we have said earlier, is the African coast of the Red Sea.

The best oyster-pearls have ben characterised in the various Sanskrit texts. Kauṭilya wrote:

> स्थूलं वृत्तं निस्तलं भ्राजिष्णु श्वेतं गुरु
> स्निग्धं देशविद्धं च प्रशस्तम्
> *sthūlaṃ vṛttaṃ nistalaṃ bhrājiṣṇu śvetaṃ guru*
> *snigdhaṃ deśaviddhaṃ ca praśastam*
> (*AS*, 2.11.5)

> (That which is) big, round, without a flat surface, lustrous white, heavy, smooth and perforated at the proper place is excellent.

Buddhabhaṭṭa described (*RP*, 95):

> सितं वृत्तं गुरु स्निग्धं सुतारम् निर्मलम् तथा
> *sitaṃ vṛttaṃ guru snigdhaṃ sutāram nirmalam tathā*

> White, round, heavy, smooth, brilliant and translucent.

There are similar descriptions in *GP*, 1.69.41; *RS* 7 and *LRP*, 3.

Navaratnaparīkṣā described an excellent pearl as:

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सुवृत्तम् स्वच्छम् दोषविनिर्मुक्तम् निर्मलम् गुरुत्वम् शीतांशु विम्बसंकाशम् रेखाविहीनम्
ईदृश सर्वगुणोपेतम् मौक्तिकम्
suvṛttam svaccham doṣavinirmuktam nirmalam gurutvam śītāṃśu bimbasaṅkāśam rekhāvihīnam īdṛśa sarvaguṇopetam mauktikam
(*NRP* 85-87)

Well-rounded, transparent, free of defects and dirt, heavy, bright as the moon, without scratches, with all these virtues.

and defined *sutāra* as:

तारकाद्युतिसंकाशम् सुतारम् तत् निगद्यते
tārkādyutisaṁkāśam sutāram tat nigadyate
(*NRP* 85)

A good pearl is *sutāra*, which throws out starry beams.

Maṇimālā (304-306) described a good pearl as *ghana* dense, *succhāya* projecting fine shadow, *asphuṭita* not indented and resembling *śvetakāca* white glass.

Pearls originating from different geographical sources were known to have specific features (*AM*, 109-113; *Bṛ. Saṁ.*, 81.3-6; *NRP*, 71-74; and *MM*, 288-290). The pearls from Sri Lanka were described as multi-shaped, glossy, swan white and large; those from the Tāmraparṇī river estuary are white with a slight red tinge and bright; the ones from Paraloka (Travancore) are blackish, white or yellow. Saurāṣṭra pearls are of intermediate size with the lustre of butter. The Persian pearl is yellow, lustrous and heavy (*Bṛ. Saṁ.*, 81.3-6). *Navaratnaparīkṣā* described:

रुक्मिणी आख्या भवेत् शुक्ति तस्याम् जातं प्रमौक्तिकम्।
निर्मलम् कुंकुमच्छायम् जातीफलसमम् वरम्।।
rukmiṇī ākhyā bhavet śukti tasyām jātaṃ pramauktikam ।
nirmalam kuṃkumacchāyam jātīphalasamam varam ।।
(*NRP*, 71; also *AM*, 112 and *MM*, 290)

There is a particular kind of oyster called *Rukmiṇī* which produces clear pearls which are shaded like saffron and as large as *jātī* fruit or nutmeg'.

Kauṭilya described (*AS*, 2.11.4) the defective pearls as 'lentil-shaped, triangular, tortoise-shaped, semi-spherical, layered, coupled, cut up, rough, spotted, gourd-shaped, dark, blue and badly perforated'. The statements on the defects of pearls mentioned in the other Sanskrit texts (*RP*, 96-101, *AM*, 118-121, *NRP*, 75-84,

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ARP, 29, *LRP*, 4 etc.) were collated in *Maṇimālā* (313-321) as follows.

If any part of an oyster remains fast attached to a pearl, the defect is called *śukti-lagnadoṣa*. *Mīnākṣaḥ* is the pearl with marks like the eyes of a fish. When a pearl is without lustre and shade, it is said to have the *jaṭhara* defect. *Atirakta* has the shade of a coral. If a pearl has three bracelet-like streaks, it is called *trivṛtta*. *Cipita* pearl is not perfectly circular; the triangular one is *tryasra* and the *kṛśapārśva* is a pearl with a broken side (*MM*, 313-321; see also *AM*, 118-121).

Skanda Purāṇa reported (*SP*, 23. 105-106) that the oyster pearl samples were given different names depending upon their colour and lustre : *vaiṣṇava* (blue), *māhendra* (yellow), *yāmya* (cloud-colour), *vāyavya* (red), *āgneya* (slight red) and *vāruṇa* (pure and white).

Like diamond, ruby, etc. pearls were also classified into four 'castes': brāhmaṇa (white), kṣatriya (red), vaiśya (yellow) and śūdra (black) (*MM*, 250, 263-64, 292-94, 299-301). Somewhat more scientific of a categorisation was attempted by declaring that pearls could acquire characteristics of any one of the five elements: *kṣiti* or earth (corresponding pearls are heavy), *ap* water (cool and white), *tej* energy (light), *marut* air (brittle), *vyom* sky (pearls are soft and light) (*MM*, 296-298). Another alternative postulate was that a pearl could be formed under the influence of three things:

> water (when the pearl becomes transparent and soft), energy (then round and bright) or air (when the pearl is tender and light).

For fish-pearls, three influences were listed as air, bile and cold. Three binary and one ternary influences were also deemed to be possible, and hence there could arise seven different varieties of pearls (*Maṇimālā*, 259, 260 and 274-276).

Pearl Market in India

There were extensive pearl-trading activites in India for which we have several historical records. Corroborative proofs exist in the Sanskrit literature referring to: (a) procedures for testing and cleaning pearls, (b) the pricing pattern, (c) various ornaments made of pearls and so on.

The *Ratnaśāstras* recommended that whenever doubts arose as to whether a particular sample of pearl was genuine or not, experts should be immediately consulted (*MM*, 322); they were supposed to conduct specific tests (*AM*, 166) :

> परीक्षा तत्र कर्तव्या रत्नशास्त्रविशारदैः
>
> *parīkṣā tatra kartavyā ratnaśāstraviśāradaiḥ*

One test-procedure consisted of immersing the sample, suspected to be a fake

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pearl, in hot oil mixed with a pinch of common salt, as the first step. Then the sample had to be soaked overnight in water, and rubbed with dry cloth and grains of paddy. If the colour did not fade, the pearl was considered to be genuine. (*RP*, 104-105; *GP*, 1.69. 39-40 and *MM*, 323-325). Another method was suggested in *Agastimata*. The sample was to be mixed with salt and cow's urine, and the mixture heated over fire. Then it had to be rubbed with a quantity of chaff. A false pearl would be reduced to fragments on this treatment, while a real one would shine more brightly. (*AM*, 167-169 and *MM*, 326-327).

The steps narrated above amounted to cleaning of genuine pearl as well, an object for which additional procedures were recommended. Pearls could be cooked in the juice of lemon and then rubbed with finely chopped carrot, when the samples could be bored quickly. Alternatively, pearls could be cooked in a *matsyaputa* or a fish-shaped crucible, with milk, water and lime-water in three successive steps. These were finally cooked in condensed milk, and then rubbed with clean cloth, when the real pearls were expected to shine brilliantly (*GP*, 1.69.35-37 and *MM*, 328-329); *Garuḍa Purāṇa* noted that this method had been originally recommended by Vyāḍi, the great ancient gemmologist (*GP*, 1.69.37). A Sri Lankan method was to put a white pearl, shining like glass, together with gold, one-hundredth of it by weight, in mercury for some time (adsorption of the gold amalgam provided a surface-coat?) before using it as an ornament. (*GP*, 1.69.38).

A fairly long tariff of prices for the pearls was provided in the ancient Sanskrit texts such as *AM* 129-164; *Bṛ. Saṁ.*, 81.9-19 and *RP*, 77-94, *GP*, 1.69.25-34, etc. The tariff was usually divided into two parts for: (1) one single pearl of different units of weight, and (2) various numbers of pearls weighing a *dharaṇa*. Varāhamihira noted that when the weight of a pearl increased from one to two and four *māṣakas* (one *māṣaka* equals approximately one gram), the price in *kārṣāpaṇa* jumped from 135 to 800 and 5300, i.e., 6 and 39 times respectively. The extended table indicated that price (*P*) increased non-linearly with the weight (w) of the pearl; *P* is proportional to w^n where *n* is in between two to three. Varāhamihira gave the prices in both *kārṣāpaṇa* and *rūpaka* which could have been two names of the same coin. Buddhabhaṭṭa gave the prices in *rūpaka* alone (*RP*, 77-85).

Varāhamihira recorded that small pearls were sold in numbers or in groups of one *dharaṇa*. When the number of pearls weighing one *dharaṇa* (6.4 *māṣakas*) was 13, the price was 325 *rūpakas*. As the number for one *dharaṇa* weight went on increasing, the price fell steadily, presumably because the size went on decreasing. 40 number, 100 number and 500 number (one *dharaṇa*) collections cost 50, 25 and 3 *rūpakas* respectively. 13, 16, 20, 25, 30, 40, 55 and

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80 or more pearls weighing a *dharaṇa* were given specific names: *pikkā*, *piccā*, *arghā*, *ardhā*, *ravaka*, *siktha*, *nigarā* and *cūrṇā* respectively. (*Bṛ. Saṁ.*, 81.17). Buddhabhaṭṭa gave another list: *guccha* (13), *dārvikā* (16), *śuvaka* (20), *siktahasta* (30), *sikta* (40), *makaraśīrṣa* (60), *kūpya* (80-90) and *pūrṇa* for 100, and above number weighing one *dharaṇa* (*RP*, 86-92). *Garuḍa Purāṇa* gave a similar tariff (*GP*, 1.69.27-34) closely resembling that in *Ratnaparīkṣā*.

The fact that the necessity of coining such nomenclatures (as mentioned in the previous paragraph) was felt, shows that there must have been in the ancient India brisk trade in pearls. The differences in the nomenclatures used by Varāhamihira and Buddhabhaṭṭa shows that their texts refer to practices in different regions or periods. It was made clear in all the ancient texts that the price tariff was for **good** pearls only. Discoloured and/or disfigured pearls fetched lower prices at specified rates of discount (*Bṛ. Saṁ.*, 81.18-19).

In the ancient India, various names were ascribed to pearl necklaces of different kinds. There are similarities as well as some distinctions in the two lists given by Kauṭilya (*AS*, 2.11.6-27) and Varāhamihira (*Bṛ. Saṁ.*, 81.31-36). A pearl-necklace four cubits long and consisting of 1008 strings, was mentioned as *indrachanda* by Kauṭilya and *induchanda* by Varāhamihira. Half that number i.e., 504 strings and 2 cubits made it *vijayachanda*, the same name having been used by both. Similar names were mentioned by both for smaller number of strings: *hāra* (108), *ardha-hāra* (64), *raśmikalāpa* (54), *guccha* (32), *nakṣatramālā* (27), etc.; *ekāvalī* was single-stringed containing any number of pearls, and *yaṣṭi* the same with a gem of different kind in the middle. There were some omissions and additions by both which showed that various combinations of pearls, other gems, gold, etc. went on changing with the passage of time.

Origin of Pearls: The Mythological Theory

We have indicated earlier that the ancient Sanskrit texts propagated the view that gems on the earth had been produced from different constituents of the body of the slain demon Bala. His teeth were converted to pearls. *Ratnaparīkṣā* (*RP*, 72-74) and *Garuḍa Purāṇa* (*GP*, 1.69.20-22) described that the seeds (Bala's teeth) fell from the sky along with water from the clouds, and both together entered the oyster shell and were converted into pearls. *Agastimata* (*AM*, 107) provided the same description.

Maṇimālā quoted a Sanskrit text (*MM*, 271) saying that twenty-seven kinds of pearls were generated in accordance with twenty-seven different stellar constellations, as Bala's teeth fell over a long period of time. Nine of these kinds were heavy, nine intermediate in density and the remainder nine kinds were

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light. The best pearls which (originated and still) originate in water drops falling upon oysters, when the sun rests on the *Swātī* (Arcturus forming the fifteenth lunar asterism) star, are flawless and bright (*NRP*, 69 and *MM*, 286):

स्वात्याम् स्थिते रवौ मेघैर्मुक्ता ये जलबिन्दवः
ते गीर्णाः शुक्तिभिर्मुक्ता जायन्ते निर्मलत्विषः
svātyām sthite ravau meghairmuktā ye jalabindavaḥ
te gīrṇāḥ śuktibhirmuktā jāyante nirmalatviṣaḥ

Similar descriptions involving the beneficial influence of the *Swāti* star were given in other texts:

पतिता जलधेर्मध्ये समुत्पन्नात् च शुक्तिकाः।
स्वाति पर्जन्य संयोगात् शुक्तिगर्भं विभर्ति सा।।
patitā jaladhermadhye samutpannāt ca śuktikāḥ ।
swāti parjanya saṃyogāt śuktigarbhaṃ vibharti sā ।।
(*AM*, 108)

सर्वेषु आकरेषु च शुक्तिपुटे स्वाति ऋक्षे जलयोगे
जायन्ते मौक्तिकानि सर्वालंकार जनकानि।।
sarveṣu ākareṣu ca śuktipuṭe swāti ṛkṣe jalayoge ।
jāyante mauktikāni sarvālaṁkāra janakāni ।।
(*RYP*, 50)

Maṇimālā further added (*MM*, 287) that the size of the pearls varies in strict concomittance with the size of the water drops falling upon oysters, i.e., a large drop producing a proportionally large pearl, and a small drop, a proportionately small one.

Conclusion

We have narrated the salient points on the gem minerals as mentioned in the ancient Sanskrit texts. The chronological evolution of the concepts related to *Ratnaśāstra* or Indian gemmology is a vast subject which merits further historical research. We have presented merely a bird's-eye view on the subject.

Looking from a late twentieth century viewpoint it is quite obvious that modern concepts on elements, molecules, physical properties etc. related to minerals were not yet known to the ancient gemmologists. As we would notice later, the concept of *sattva* or metal inherent in an ore was evolved in the *Rasaśāstra* texts, but this did not amount to conceptualisation of elements and chemical compounds in the modern sense. Gems were classified according to colour which was noted to be misleading in many cases, and hence the second

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property namely relative hardness was noted and utilised for the identification of specific gem minerals. In this chapter we have classified the gems according to hardness and discussed the same in that order of decreasing hardness, from diamond to pearl.

In the case of samples supposed or expected to be diamond, specific gravity was considered to be an important property in view of the possible contamination with heavier minerals such as zircon. But it is doubtful whether accurate measurements of the specific gravity of gems were made in anicent India. Al-Biruni attempted some measurements (S.M.R. Ansari, 'On the Physical Researches of Al-Biruni', In *Indian Journal of History of Science*, Vol. 10, No.2, November 1975, pp. 198-217). The phenomenon of birefringence *dvichāyā* was known, but the concept of refractive index had not yet been evolved.

Most of the authors of the *Ratnaśāstra* texts believed in, and recorded, the myth regarding the origin of the gems from different parts of the body of the slain demon Bala. Varāhamihira also mentioned about these myths, but it is doubtful whether he believed in them. In his *Bṛhat Saṁhitā* he hinted at a more scientific explanation :

> Gems, they say, were born of the bones of the demon Bala, while others state that they were born of sage Dadhīci, yet others declare that the wonderful variety of gems is caused by the characteristic qualities of the earth.
>
> केचित् भुवः स्वभावाद् वैचित्र्यं प्राहुः उपलानाम्।
> *kecit bhuvaḥ svabhāvād vaicitryaṃ prāhuḥ uplānām* ।
> (*Bṛ. Saṁ.*, 80.3)

Varāhamihira did support fresh thinking on scientific matters. This is evident from his bold advocacy for the modern theory of eclipses, negating the myth of Rāhu. However, he was much too respectful towards the ancient traditions to defy them absolutely. He also believed in astrology (besides astronomy) and prognostication. Thus, it is not surprising that his suggestion regarding the gems arising out of geological forces (rather than mythical events) was not seriously pursued either by himself or by his followers. To make matters worse, the castiest approach towards categorisation and use of gems became more entrenched with the passage of time.

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8

Non-Gem Minerals and Metals in Ancient Texts Culminating to *Rasaśāstra*

So far, we have discussed the references to minerals and metals contained in the Vedic and post-Vedic literatures, and to the gems in the Indian gemmology texts known as *Ratnaśāstra*. It is surprising that Indians, who had known the uses of non-gem minerals and the manufacture of copper and iron from their respective compounds in the Pre-Historical period, wrote little about these materials. This may be explained in terms of gradual casteist division and compartmental isolation between the low caste metalsmiths and the high-caste philosopher-cum-writers.

Fortunately for our purpose, some writers took interest in (a) atomic constitution of matter and (b) medical uses of minerals, metal oxides and sulphides, etc., which involved reduction of minerals to the metallic stage and subsequent oxidation or reaction with sulphur. The chemistry and therapeutic aspects of medicines, both organic and inorganic, were covered in the alchemical texts called *Rasaśāstra*. Although the alchemical texts evolved in India during the middle of the first millennium after Christ, their basis had been laid earlier over centuries, and we would discuss this background first.

The concept of five elements as the basis of the material universe occurs in the *Āraṇyakas* and the *Upaniṣads* (*c*. eighth century BC), and thus antedates the Greek theory of Empedocles (*c*. fifth century BC). *Chāndogya Upaniṣad* mentioned that the universe originally existed in a highly refined or potential form like a seed which gradually evolved into grosser material stuff. The matter was created from energy. The *Vedānta* philosophy distinguished between two kinds of *ākāśa* : *purāṇaṁ kham* or *kāraṇākāśa*, the motionless, primordial matter-rudiment, and *kāryākāśa*, materialisation from non-atomic *ākāśa*. The twofold aspect of

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ākāśa, non-material and material, related to each other as cause and effect was a very significant concept in the Indian Philosophy. (Seal, 1958:121)

Kapila the originator of the *Sāṁkhya* philosophy proposed that *tanmātras* or infra-atomic entities, derived from the conscious principle, gave rise to *aṇus* or atoms and five kinds of grosser elements or *bhūtas* : space or ether (*ākāśa*), air (*vāyu*), fire (*tejas*), water (*ap*) and earth (*kṣiti*). Patañjali of the second century BC perfected the *Sāṁkhya* system of philosophy. According to this philosophy, the *prakṛti* or nature is an equilibrium of three principles: *sattva*, the essence or intelligence stuff, *rajas* the energy stuff and *tamas*, the inertia or the matter stuff.

Kaṇāda, the founder of the *Vaiśeṣika* system of philosophy was primarily concerned with the material aspects of the universe. He postulated only four kinds of elements: *kṣiti*, *ap*, *tejas* and *vāyu*. In his view *ākāśa* is non-material and serves merely as an inert substratum for sound and energy to travel. The later-day astronomer, Āryabhaṭ also accepted this principle of **four** elements, ignored the Vedāntic concept of twin forms of *ākāśa* and the origin of matter from non-matter. Kaṇāda believed that light and heat are different forms of *tejas* and the atoms or *aṇus* are eternal, ultimate, indivisible and infinitesimal. (Gough, 1975: 138)

Vaiśeṣika Sūtra (4.1.1-2) states that *sat akāraṇavat nityam tasya kāryaliṅgam* atoms are eternal, uncaused, non-destructive and are inferred from their effects. Kaṇāda's conception of atoms bears resemblance to that of the Greek philosopher Democritus (*c.* 470-360 BC). H.T. Colebrooke and H.H. Wilson concluded that the resemblance is explained in terms of Greeks being the borrowers. According to the Greek tradition, Thales, Empedocles, Democritus, etc. undertook journey to the oriental countries in order to study philosophy.

According to the *Vaiśeṣika* system, atoms possess an intrinsic vibratory or rotatory motion (*parispanda*) and combine to form binary molecule (*dvyāṇuka*), ternary (*tryāṇuka*), etc. Chemical combination occurs under the influence of heat corpuscles. Atoms though eternal in themselves, are non-eternal as aggregates.

The Buddhist schools accepted the atomic view of matter with some qualifications. According to the Jainas, interlinking between atoms and molecules in *pudgala* or matter must precede all compound formations: *aṇu* (atom) to *skandha* (aggregate). (Ray, Priyada, 1956: 46-47; Sikdar, 1970) A detailed presentation of the atomic theory and chemical combination found in Umāsvāmī's (*c.* AD 40). *Tattvārthādhigama-sūtra* bears some crude resemblance to the 'dualistic hypothesis' of Berzelius, propounded in the nineteenth century.

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Vātsyāyana of the fourth century AD elaborated on chemical changes initiated by external or internal heat (*Vātsyāyana-bhāṣya*, ch. IV, *āhnika* 1, *sūtra*, 47). The above postulates, as well as the Greek theories of atomism could not advance very far on account of lack of experimentation, only which could spur further investigation in this scientific topic. (Ray, Priyada Ranjan, 1966 and 1986: 136-51) Thus the Indian expertise on minerals and metals remained isolated from the theoretical notions of matter and its constitution.

Saṁhitās of Caraka and Suśruta

The above two *saṁhitās* along with *Aṣṭāṅgahṛdaya* by Vāgbhaṭa, known as the 'great trio' of ancient Indian medical texts, provide many references to the uses of minerals and metals in medicine.

Caraka wrote (26.12) that there is 'nothing in the world which does not have therapeutic ability'. Three types of matter were recognised.

जंगम् उद्भिद पार्थिवम्

jaṅgam udbhid pārthivam

(1.68)

— animal, plant and mineral.

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The mineral-cum-metals were further subdivided:

सुवर्ण समला: पंचलोहा: ससिकता: सुधा।
मन:शिलाले मणयो लवणं गैरिकांजने।।

suvarṇa samalāḥ pañcalohāḥ sasikatāḥ sudhā ।
manaḥśilāle maṇayo lavaṇaṃ gairikāñjane ।।

(1.70)

gold, five *lohas* (copper, silver, tin, lead and iron) their by-products, silica, red and yellow arsenic, gems, salt, collyrium, etc.

Five varieties of salt were described:

सौवर्चलं सैन्धवं च विडम् औद्भिदम् एव च।
सामुद्रेण सहैतानि पंच स्यु: लवणानि च।।

sauvarcalaṃ saindhavaṃ ca viḍam audbhidam eva ca ।
sāmudreṇa sahaitāni pañca syuḥ lavaṇāni ca ।।

(1.88)

sauvarcala (saltpetre, sodium/potasium nitrate), *saindhava* (rock salt), *viḍa* (ammonium chloride) *audbhida* (plant product,

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potassium carbonate?) *sāmudra* (sea salt), etc. These were used for improving digestion and as medicines.

Young plant *Butea frondosa* used to be dried, reduced to ashes and lixiviated with water to produce potassium carbonate, *audbhida* salt or *kṣāra* (alkali).

Minerals like sulphate of copper, sulphate of iron (*aśmakāśīsa*), realgar (*manaḥśīla*), orpiment (*haritāla*), and sulphur (*gandhaka*) were prescribed for external application in many skin diseases. Under the recipe of a pearl compound, there is mention of pearl, powder of iron, copper and sulphur. The metals were obviously used after being roasted with sulphur. This was one of the early landmarks of *rasaśāstra* or Indian alchemistry. The text also described the uses of coral, *lapis lazuli*, ashes of conch-shell, calces of iron and copper ('killing' of metals to produce oxides), sulphide of antimony (*sauvirāñjana*), etc. The mention of coral (*vidruma*), emerald (*marakata*), *romaka*, etc. indicated that a part of the *Saṁhitā* was written after the trade with Rome had been started.

Elaborate descriptions about the preparation and properties of alkali carbonates (prepared by lixiviation of burnt plant ash) and caustic alkali (lixiviation of burnt limestone, conch-shell and bivalve shells) were provided in *Suśruta Saṁhitā*. Mild (*mṛdu*), medium strength (*madhyama*) and strong (*tīkṣṇa*) solutions of alkali (*kṣāra*) were prepared by lixiviation and successive operations of evaporation and concentration. There was widespread use of caustic alkali solutions for cauterisation in surgery. The application of the pungent acid of *kañjika* (fermented rice water, i.e., crude vinegar) was known to relieve the burning sensation and taste of the 'fire-like hot alkaline caustic', 'just as fire is extinguished by water'. Distinction was made between *yavakṣāra* (factitious carbonate of potash) and *sarjikākṣāra* (carbonate and bicarbonate of soda from river bed alluvium).

Suśruta recommended as drugs, the oxides (calces) of tin, lead, copper, silver, iron and gold which were prepared by roasting the metals with minerals like alum-earth and red ochre. For the roasting of iron, thin leaves of the metal were smeared with the levigated powder of the salts including common salt, saltpetre, sulphate of magnesia, and heated in the fire of cow-dung cakes. This process, called *ayaskṛti*, affected the metal and produced oxides and oxy-salts. Mercury was **not** well-known during Suśruta's time. Two types of pyrites (*mākṣika*) known to 'resemble gold and silver' were evidently chalcopyrite and ordinary iron-bearing pyrite. Compounds of arsenic (*phenasama bhasma*) and orpiment were recognised as poisons.

Both Caraka and Suśruta mentioned crude processes of calcination, distillation (of liquor from fermented juices), sublimation, steaming, fixation, etc. They

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distinguished between chemical compounds and mechanical mixtures.

At this stage, it may be useful to mention the compilatory nature of the *Saṁhitās* of Caraka and Suśruta. The two texts recognised that *Āyurveda* or the early medical science of India was an *upaveda* of the *Atharvaveda*. Even in the Atharvavedic age, minerals and metals were used as medicines (see chapter 3). There must have been many medical texts between the *Atharvaveda* and the *Caraka Saṁhitā*.

Caraka Saṁhitā is based on an earlier work of Agniveśa, whose teacher Ātreya taught medicine in the University of Takṣaśilā (Taxilā) during the age of Buddha. The *Saṁhitā* must have been redacted in several versions by Carakas of successive centuries, till the final version was organised by Dṛḍhabala, the court physician of King Kaniṣka (AD 100). Suśruta was a teacher in the University of Varanasi during Buddha's time, and a disciple of Dhanvantari. His surgico-medical treatise was gradually elaborated over centuries, and the extant version is generally believed to be an edition executed by the famous Buddhist chemist Nāgārjuna. Thus the two *Saṁhitās*, containing various references on minerals and metals, depict Indian progress on the knowledge of these materials over centuries (fourth century BC to second century AD).

During the above period, considerable progress about the sciences of minerals, metals were made. Kauṭilya mentioned *rasapāka* which has been translated as 'distillation and condensation of mercury' by Shamashastri, and as 'chemistry' by Jolly and Schmidt. During Aśoka's reign, techniques were developed for quarrying laterite and sandstone rocks, mining gold deposits at Kanakagiri or Subarṇagiri (near the present Haity gold mines and Raichur), rock-cutting and polishing granite-gneiss rock pillars, stone-railings and caves at Karmachampar, Barabar, Gaya etc. (Brown, 1956; Lahiri, 1971: 495; Roy, 1946: 117)

Yājñavalkya and Patañjali

In the pre-Christian era, Yājñavalkya wrote about minerals and metals in his *Smṛti*; the *Śloka* 181 of *Vyavahāra* dealt with the relative deterioration of metals when treated with fire: 'Gold does not suffer deterioration, of silver is two *palas*, of tin and lead eight, of copper five and of iron ten *palas* per hundred'. In *Ācārādhyāya*, 190, he recommends that

त्रपुसीसकताम्राणां क्षाराम्लोदक वारिभिः।
भस्माद्रिः कांस्यलोहानां शुद्धिः प्लावो द्रवस्य च।।
trapusīsakatāmrāṇāṃ kṣārāmlodaka vāribhiḥ ।
bhasmādriḥ kāṁsyalohānāṃ śuddhiḥ plāvo dravasya ca ।।

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tin, lead and copper may be cleaned by alkali and acid water whereas iron and *kāṁsya*, copper alloy (could it mean brass also as suggested by Roy, 1946:108? Brass was mentioned as *riti* by Caraka and Manu) should be cleaned by ash and water. Yājñavalkya advised the kings to use copper plates to write deeds (*Ācāra*, 318-320).

Patañjali was a contemporary of Puśyamitra Śuṅga (*c.* 187-151 BC). He was not only a great grammarian, composing the famous *Mahābhāṣya* of Pāṇini, but also a philosopher of mind and **body**. Bhoja commented in his *Nyāyavartika*.

> योगेन चित्तस्य पदेन वाचां मलं शरीरस्य तु वैद्यकेन
> योऽपाकरोत् तं प्रवरं मुनीनां पतंजलिं प्रान्जलिः आनतोऽस्मि
> *yogena cittasya padena vācāṃ malaṃ śarīrasya tu vaidyakena*
> *yo'pākarot taṃ pravaraṃ munīnāṃ patañjaliṃ prāñjaliḥ ānato'smi*

that he was the physician of the mind (vide his *Yogasūtra*) and of the body. Patañjali was interested in alchemy and medicine, and recommended the use of minerals and metals for health and other purposes. Al-Beruni quoted Patañjali's view that 'one of the methods leading to liberation is *Rasāyana*'. (Sachau, 1983: Vol.1, p.189) Nāgārjuna, who is acknowledged as the Father of Indian Chemistry considered Patañjali to be a leader in alchemy.

Patañjali wrote on metallurgy and his *Lohaśāstra* has been partially quoted by other authors. He observed that the Mauryas, in order to replenish their treasury, had sold metallic images of gods like Śiva, Skanda, etc. He mentioned the use of vessels made of bronze (and brass?) as containers of milk products:

> बहुक्षीरघृतमोदनं कांस्यपात्र्याम् भुन्जीरन्निति।।
> *bahukṣīraghṛtamodanaṃ kāṁsyapātryām bhuñjīranniti* ।।
> (*Mahābhāṣya*, 8.2.3.1)

He also mentioned the use of trapu or tin (6.1.69.5 and 6.1.85.17 in *Mahābhāṣya*).

Patañjali's Successor : Nāgārjuna

Nāgārjuna, the alchemist, is widely regarded as the inventor of distillation and calcination. According to Vṛnda and Cakrapāṇi, Nāgārjuna was the inventor of the use of *kajjali* or Cinnabar (mercuric sulphide HgS) to produce mercury. The later day *Rasaśāstra* texts eulogize him as the pioneer in metallurgy (*dhātuvāda*) and the use of metallic salts in medicine. Ḍallaṇa makes him the redacter of the *Suśruta Saṁhitā* :

> प्रति-संस्कर्तापीह नागार्जुन एव
> *prati-saṃskartāpīha nāgārjuna eva*
> (*Nibandha-Saṁgraha* I)

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Nāgārjuna compiled several medical texts related to metals and metallic salts: *Lauhaśāstra*, *Kakṣapuṭatantra*, *Rasaratnākara* (on which we would comment later), etc. Several medical recipes, based on *haridrā* (turmeric), *abhra* (mica), etc. and formulated by Nāgārjuna, used to be written on stone slabs in Pāṭaliputra for the public. (Mukhopadhyaya, 1923)

Rasāyana has been defined by Caraka (1.2.6) as the science or medicine which promotes longevity, retentive memory, health, virility, etc. Few experts in *Rasāyana* who might have preceded Nāgārjuna were Vyāḍi or Vyālācārya and Māndavya of whom we do not know very much.

We would now comment on the date of Nāgārjuna and his precise identity. Al-Beruni mentioned the popularity of the Indian Science *Rasāyana*, and that the Indians were 'inclined towards the mineralogical method of alchemy'. In that connection, he wrote that 'a famous representative of this art was Nāgārjuna, a native of the fort Daihak near Somnāth. . . . His book is very rare . . . He lived nearly a hundred years before our time'. (Sachau, 1910, 1983: 189) Quoting Al-Beruni, many authors have put Nāgārjuna in the ninth/eighth century AD. (Ray, 1956:116-18) However as Filliozat (1951) has pointed out, Hiuen-Tsang attested in AD 630 that the alchemist Nāgārjuna had lived much before his time: 'Nāgārjuna lived in Sangharama not far to the south of the city Kosala or Berar; he was well-practised in the art of compounding medicines which provided long life; Sadvaha-rāja had partaken of this mysterious medicine'. (Beal, 1884, 1969: 212)

It is quite likely that the original Indian source from which Kumārajīva wrote Nāgārjuna's biography in Chinese (AD 405), had mixed up the famous alchemist-cum-tāntric teacher, the contemporary of Yajñaśrī Gautamīputra Sātavāhana or Sātakarṇi (AD 166-96 or 174-203), with the (Mādhyamika) philosopher Nāgārjuna who was probably a contemporary of King Kaniṣka (AD 78-102) (Nalinākṣa Dutt's view in Majumdar, Volume 2, 1980: 388). We are concerned with the alchemist (vide Sylvain Lévi). The suggestion that the alchemist and the philosopher were the same person is difficult to accept.

The alchemist Nāgārjuna lived in the monastery of Kosala or Berar, modern Chāndā (near Nāgpur or Amrāvatī), and was a friend of the Sātvāhana King addressed to whom he wrote a book: *Suhrillekha* (Letters to a Friend). Hiuen-Tsang wrote that when the king had fallen short of gold, Nāgārjuna used a 'divine decoction and converted some stone into gold with which four statues of Buddha were made'. (Beal, 1884, 1969: 216). The allusion was most probably to the yellow or gold-coloured brass, widely publicised by Nāgārjuna.

We quote two very relevant passages from Nāgārjuna's *Rasa-Ratnākara* (*RR*):

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किमत्र चित्रं रसको रसेन . . .
. . . क्रमेण कृत्वाम्बुधरेण रंजितः
करोति शुल्वं त्रिपुटेन कांचनम्
kimatra citraṃ rasako rasena . . . .
. . . krameṇa kṛtvāmbudhareṇa rañjitaḥ
karoti śulvaṃ tripuṭena kāñcanam
(*RR*, 3)

What wonder is that calamine (*rasaka* or zinc ore calamine) roasted thrice with copper (*śulva*) convert the latter into gold (actually gold-coloured brass).

क्षारस्नेहैश्च धान्याम्लै रसकं भावितं बहु।
ऊर्णा लाक्षा तथा पथ्या भूलता धूमसंयुतम्।।
मुकमुषागतं ध्मातं टंकणेन समन्वितम्।
सत्वं कुटिलसंकाशम् पतते नात्र संशयः।।
kṣārasnehaiśca dhānyāmlai rasakaṃ bhāvitaṃ bahu ।
ūrṇā lakṣā tathā pathyā bhūlatā dhūmasaṃyutam ।।
mukamuṣāgataṃ dhmātaṃ ṭaṅkaṇena samanvitam ।।
satvaṃ kuṭilasaṃkāśam patate nātra saṃśayaḥ ।।
(*RR*, 31-32)

Rasaka (Calamine) digested repeatedly with fermented paddy-water, natron and clarified butter, and mixed with wool, lac, *Terminalia Chebula* and borax and roasted in a covered crucible, yields an essence of the appearance of tin; of this there is no doubt.

The above passages from Nāgārjuna are the earliest literary references to the ancient art of making brass and zinc. The latter passage quoted (*RR*, 31-32) vividly recalls the distillation of zinc, 'the falling of the tin-like metal'. The ore was named *rasaka* because it yielded a distillation product like *rasa* or mercury. Much later, the metal zinc was named *yaśada*, *yaśadāyaka*, *yaśatva* (later colloqually *yastā* or *dastā*), 'that which gives fame', a reference to the gold-like colour of its alloy.

Brass has been widely used in India since the pre-Christian era of Taxila. We may also mention the first century BC brass coins of Dhanadeva and Āryavarmā of Ayodhyā, second century AD cast brass casket at Mānikyālaya, numerous fifth/sixth century brass statues of Buddha, seventh century AD unfinished brass *vihāra* or convent at Nālandā etc. Hiuen-Tsang mentioned widespread use of *teou-shih* or brass in India.

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Alchemists like Nāgārjuna were interested in the therapeutic use of metallic salts of mercury (*rasa*), zinc (*rasaka*), etc. Minerals or metal salts were stated to provide hardness to metal as well as to body :

वलीपलितनाशश्च तथा कालस्य ध्वंसनम्।
यथा लोहे तथा देहे क्षमते नात्र संशय:।।
valīpalitanāśaśca tathā kālasya dhvaṃsanam ।
yathā lohe tathā dehe kṣamate nātra saṃśayaḥ ।।

In his *Rasa-Ratnākara* (*RR*), Nāgārjuna dwelt on several other topics related to minerals and metals: purification of *rājāvarta* or *lapis lazuli* (*RR*, 1), extraction of metals from chalcopyrite (*mākṣika*), lead ore (*capala*), purification of crude molten copper by poling (*RR*, 14), extraction of metal from *vaikrānta* (*RR*, 23-25), extraction of metal from *vimala*, *darada* (cinnabar), etc.

The distillation of mercury from cinnabar was described:

दरदं पातनायन्त्रे पातितश्च जलाशये।
daradaṃ pātanāyantre pātitaśca jalāśaye ।
(*RR*, 37)

Pearl was stated to be soluble in vegetable acids:

एक एव महाद्रावौ अम्लकांजिकै:
मुक्ताफलानि सप्ताहं वेतसाम्लेन भावयेत्।
eka eva mahādrāvau amlakāñjikaiḥ ।
muktāphalāni saptāhaṃ vetasāmlena bhāvayet ।
(*RR*, 50-51)

Nāgārjuna described the use of *navasāra* or salt ammoniac (*RR*, 2.1), vegetable recipes in metal making, various tools and so on.

There is no doubt that the alchemist Nāgārjuna belonged to the latter half of the second century AD (Bose, Sen and Subbarayappa, 1971:41) although it is not clear whether he was also the celebrated philosopher, and whether the present form of *Rasa-Ratnākara* was edited in the eighth century. (Ray, 1956:118)

The *Yavanajātaka*

Ever since Alexander's invasion and particularly after the decline of the Maurya empire, the Greeks or Ionians, known in India as the **Yavanas** intruded into India and interacted with the Indians. Some of them contributed to the cultural life and the scientific pursuits in the sub-continent.

Yavaneśvara and Sphujidhvaja were Indianised Greeks settled in the

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domains of the Western Kṣatrapas in Gujarat, Mālwā and Rajasthan. The date of Yavaneśvara corresponds to the middle of the reign of Rudradaman I, the greatest of the Western Śakas. Yavaneśvara's Greek book on astrology and mineralogy (AD 150) was translated one century later into Sanskrit text *Yavanajātaka* by Sphujidhvaja (AD 270). An English translation of the same has been provided by David Pingree (1978).

It may be noted that both Nāgārjuna and Yavaneśvara belonged to the second half of the second century AD. As a matter of fact, the Sātavāhana King Gautamīputra Sātakarṇi claimed to have come into conflict with the Śakas and Yavanas of Kāṭhiāwār and Mālwā. Thus, the book *Yavanajātaka* reflects the state of knowledge on minerals and metals prevalent in India during Nāgārjuna's time.

The verses 7-15 in the chapter 62 of the text of *Yavanajātaka* contain references to minerals and metals. The word *dhātu* was used to indicate metals as well as minerals. *Dhātus* were known to belong to two categories: *dhāmya* (bright) and *adhāmya* (dull). *Dhāmya lohas* (metals) were known to be of six types: *suvarṇa*, *raupya*, *trapu* (tin), *sīsā* (lead), *tāmra* (copper) and *kṛṣnāyas* (iron). *Mauktika* (pearl), *yukta* (alloy) and *śastram* (steel) also belonged to the *dhāmya* (bright) category.

Some of the dull materials or *adhāmya dhātu* listed were: *manaḥśilā* (red arsenic), *hiṅgulaka* (cinnabar), *amlaśāla* (acidic sorrel), *saurāṣṭrajāta* (some mineral earth from Saurāṣṭra or Gujarat), *rasaka* (calamine or zinc ore), *paṅka* (ointments), *añjana* (unguents), *bālikayā samāna* (powdery stuff). *Śilā* and *āla* were abbreviations of *manaḥśilā* (red arsenic sulphide) and *haritāla* (yellow arsenic sulphide) respectively.

Some of the materials and minerals having varieties of uses including medicinal were: *śarkarā* (sugar or sand), *kāsīsa* (green sulphate of iron), *mṛḍ* (clay), *kardama* (slime), *gairika* (red chalk, iron ore?), *tāpya* (sulphuret of iron), *mākṣika* (pyrite), etc.

It is noteworthy that Yavaneśvara mentioned *rasaka* or calamine, a zinc ore which was available in the Gujarat-Rajasthan area and, as stated by Nāgārjuna, was used for making brass.

Minerals and Metals in the Gupta Era Literatures

The political disintegration which followed the dissolution of the Kuṣāṇa empire continued right up to the beginning of the fourth century AD. The Gupta era started on AD 320 and listed till AD 570. Out of this period of two and half centuries, the first one and half (up to AD 467 when Skandagupta died), may be

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considered to be the 'golden era'. During the Gupta era, several literatures showed the sustained use of minerals and metals in India.

We may recall that at the turn of the Christian era, the Roman traders and writers like Pliny, Ptolemy, the author of *The Periplus of the Erythrean Sea* noted the diversity of gems, non-gem minerals and metals processed and used in India. The Indians were 'the first nation who employed minerals internally'. Since the first century AD. cinnabar was used for fumigations which produced speedy and safe salivations. Arsenic and arsenious acids were remedies to intermittants. Mention of stibnite, ochre, realgar in the preparation of medicines is found in Bower manuscript (second half of the fourth century AD). The Bower manuscript *Navanītaka* (Hoernle, 1893,1907) mentioned the uses of *yavakṣāra* and *sarjikākṣāra* (K and Na carbonates), copper and iron sulphates, *srotaja añjana*, Co/Sb sulphide, calx of brass, etc. in medicine.

As early as AD 531-72 Muslim students used to come from Baghdād to India to learn about Indian medicine. Later, Vāgbhaṭa (*c*. eighth century) mentioned the use of iron and copper sulphates for medicinal purposes.

Pakśilasvāmin Vātsyāyana of the middle of the fourth century AD wrote a commentary on the *Nyāyasūtra* of Gautama, the first work (*c*. second century AD) on Indian logic. Vātsyāyana Mallanāga, possibly a different person, who came later in the fifth century AD, referred to sixty-four fine arts (*kalās*) in his treatise *Kāmasūtra* which included *rūpa-ratna-parīkṣā* (testing of precious metals and stones), *dhātuvāda* (smelting of metals), *maṇirāgākarajñānam*. (the technologies of gems, colouring of glass, mines, etc.) Mining and metallurgy were standard practices in the then commercial life of India.

Aṅgavijjā and *Amarakośa*

Two important compilations made during the Gupta era provide a wealth of information regarding the material culture of the period in India; we would extract from them certain references to minerals and metals.

Aṅgavijjā is a text of the Jains written in Prākṛt by Pubbāyariya (Munipuṇyavijaya, 1957). This text dealing mainly with the science of prognostications contains useful references to the then uses of minerals and metals.

The compilation was made during the beginning of the Gupta era (fourth century AD) when the Kuṣāṇa and Kṣatrapa influences were still perceptible in the Western India. The text mentions *joṇikā* or *javanikā*, a Greek woman and several kinds of coins bearing foreign influences. *Māṣaka*, *kārṣāpana*, *nāṇaka* were ancient traditional coins of India. *Khattapaka* was however the Kṣatrapa

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coin of Rudradāman (AD 150) also known as *rudradāmaka*. *Sateraka* was the Greek gold coin 'stater' weighing 133.2 grams. *Dīnāra* was the Gupta age gold coin, but the name was derived from the pre-Christian era Roman silver coin *denarius*. *Nāṇaka* was low denomination copper coin. The Kṣatrapas used lead also for such low-value coins.

Aṅgavijjā provided a fairly long list of prevalent professions. There were *suvarṇakāras* (gold smiths), *kaṁsakāra* (bronze smith), *loṇakāra* (dealer in salt), *maṇikāra* (lapidary, dealer in gems), *kottaka* (inlayers), etc. *Dhātus* were classified in *Aṅgavijjā* into two categories: *maṇidhātu* (gems) and *loha* (metals). Probably *Yavanajātaka's* notion of *dhāmya*, something which is bright, was applied to the word *dhātu*, excluding those which are *adhāmya* or dull.

The metals used were gold, silver, copper, lead, *trapu* or tin, *hārakūḍa* or brass, *kāla loha* (pig iron), *kaṁsa loha* (bronze), *bahu loha* (many metal alloy), etc. Also mentioned were *tikkhaloha* (cast iron) and *muṇḍaloha* (wrought iron).

A special remark may be made of *hārakūḍa* or *ārakūṭa* of *Kauṭilīya Arthaśāstra* or brass. It was compared in colour with gold:

तत्थ पीतकेसु सुवन्नकं हारकूडकं चेव विन्नेयम्
पंचवरेसु सोवहवेसु य पीत एसु हारकूडकं विन्नेयम्
tattha pītakesu suvannakaṃ hārakūḍakaṃ ceva vinneyam
pañcavaresu sovahavesu ya pīta esu hārakūḍakaṃ vinneyam
(*Aṅgavijjā*, 1957:233)

The bright yellow colour of brass was considered to qualify it as a suitable replacement for gold as suggested by Nāgārjuna.

Lohitākṣa (carnelian), *masārakalla* or *marakata* (emerald), *veruliya* or *vaidūrya* (beryl), *gomeda* (zircon), *phāliya* or *sphaṭika* (quartz) were adored as gems. *Khāramaṇi* was a general name modified according to colour: *raktakhāra* (garnet), *svetakhāra* or *vimalaka* (pyrite?), *nīlakhāra* (sapphire), *kālakhāra* (galena?), etc. The gems like coral, pearl, chank- or conch-shell, ivory, etc. were separately categorised as *prāṇayonigata* or those having biological origin. The metals were beaten, *khāramaṇis* scalloped, coral and chank were rubbed (*ghaṭṭha*) and the pearls smoothened (*parimaddita*).

The eyes were decorated with collyrium (*añjana*), the brows with the lampblack, the temple with cinnabar (*hiṅgula*), orpiment (*haritāla*), realgar (*manaḥśilā*), and the lips with lac-dye (*alaktaka*). For other decorative purposes were used *geruā* (red ochre), *palepaka* (plaster), *nīlakadhātu* (ultramarine?), *sassekechunna* (blue vitriol, copper sulphate or malachite/azurite powder?).

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Nāmaliṅgānuśāsanam by Amarasiṁha (AD 450) popularly known as *Amarakośa* is one of the most celebrated lexicons in the Sanskrit language. The author was Buddhist Scholar with a strong leaning towards *Sāṁkhya* philosophy. He compiled a large number of technical words related to minerals and metals. Many of these are from the Vedic sources, Pāṇini and Kauṭilya, which we have already mentioned. We would mention here only some of the additions made around fourth century AD.

Like *Aṅgavijjā*, *Amarakośa* contained a list of different kinds of salts such as *sauvarcala* (saltpetre), *saindhava* (rock salt), *yavakṣāra* (potassium carbonate in plant ash), etc. Saltpetre, also known as *naipālī* (from Nepal) was probably used in rocket or fire-works, mentioned as *Yogavārtikā* by Daṇḍī (sixth century AD) in his *Daśakumāracarita*.

Some of the other inorganic materials used for decorative purpose were: *tutthāñjana mayuraka akṣa* (blue vitriol or copper sulphate), *sindūra* or *nāgasambhava* (red lead), *kulali* (blue collyrium), etc. *Amarakośa* provided three names for alum: *kāṁkṣi*, *tuvari* and *saurāṣṭraja*. For minerals and gems, alternative names were mentioned: *śubhra/abhra* for mica, *phala / muktā* for pearl, *kulisa / vajra* for diamond. Both *marakata* (emerald) and *vaidūrya* (beryl) were referred to.

Some of the new names for metals and alloys are found in the *Amarakośa: kupyam* — base metal, *aśmasāra* — iron, *kuśī* — wrought iron, *pārada/capala* — mercury, *sthuṇa* — iron statue, *vaṅga* — tin. It may be noted that the famous *sthuṇa* or iron pillar of Delhi was made in the Gupta era. Tin had a new name *vaṅga* (Bengal); it is significant that tin-based bronzes were being made in the Bengal area (Nālandā, etc.) using Hazārībāgh tin ore or the metal imported from Malaysia. *Ārakūṭa* continued to stand for brass. *Rīti* meant brass as well as rust or calx of brass. *Caraka Saṁhitā* had used the same word *rīti* and recommended its medicinal use. *Rītipuṣpam* meant flower-like substance from heated brass.

Amarakośa referred to an iron smith not only as *lohakāra* but also as *vyokāra*. *Kalāda* was silver smith, *śaulvika* a copper-smith, and *kāmbavika* a shell-worker.

Varāhamihira's *Bṛhatsaṁhitā*

We have earlier discussed the valuable references to gem minerals in *Bṛhatsaṁhitā* (*Bṛ. Saṁ.*), a composition belonging to the later part of the Gupta era (sixth century AD). This treatise also contains some useful references to rocks, non-gem materials and metals, which we propose to cite.

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The colour and plant associations of rocks enabled one to decide whether some rock had subsurface water. The rocks associated with *muñja* or sacrificial grass, or a colour resembling beryl or green gram were likely to yield sweet water (*Bṛ. Saṁ.*, 54.103 and 107). Land coloured like the sun, fire or ashes (igneous rock) is likely to be waterless (*Bṛ. Saṁ.*, 54.106). On the other hand:

सशर्करा ताम्रमही कषायं क्षारं धरित्री कपिला करोति
आपाण्डुरायां लवणं प्रविष्टं मृष्टं पयो नीलवसुन्धरायाम्।।

saśarkarā tāmramahī kaṣāyaṃ kṣāraṃ dharitrī kapilā karoti
āpāṇḍurāyāṃ lavaṇaṃ praviṣṭaṃ mṛṣṭaṃ payo nīlavasundh-
arāyām
(*Bṛ. Saṁ.*, 54.104)

A copper-coloured earth mixed with gravel or rocks with copper-red spots (probably allude to garnet porphyroblasts) will yield water with astringent taste; red-brown earth makes the water brackish; pale white earth salt-water and blue earth, sweet water.

Varāhamihira prescribed several methods for quarrying massive rocks, using the principle of alternate heating and cooling for disintegrating the rocks (*Bṛ. Saṁ.*, 54.112-114). Presence of horizontal and vertical joints sometimes helped in the quarrying of massive sand stones (like the Vindhyan sandstones). (Lahiri, 1971: 496) Recently a series of stone quarries has been discovered near Chunar in Mirzapur. The Maurya period massive pillar-like stones were carefully chiselled.

Mākṣika (pyrite) and *śilājatu* (bitumen) powder were recommended (*Bṛ. Saṁ.*, 76.3) as ingredients in health tonics. The use of alum as a mordant in the dyeing process were suggested:

"*Tuvari* (alum), *mañjiṣṭha* (maddar dye), *rāgabandhanī* (colour-binding)". Earlier, Pāṇini had suggested (4.1.42) the use of various dyes such as indigo, lac and red ochre; turmeric and maddar were mentioned in *Saṁyutta Nikāya*.

Bṛhat Saṁhitā described several preparations of cements or powders called *vajra-lepa*, characterised as 'paints or coatings as strong as *vajra* or diamond'. The various recipes included concentrated aqueous extracts of plant products rich in gummy and resinous substances, levigated powder of lac, resins, gummy fruits, concentrated extract of animal matters rich in glue or gelatine, etc. (*Bṛ. Saṁ.*, 57.1-7). These were used as cements in temple architecture.

The metal cement *vajra-saṅghāta* was described as :

अष्टौ सीसकभागाः कांसस्य द्वौ तु रीतिकाभागः।

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मयकथितो योगः अयम् विज्ञेयो वज्रसंघातः।।
aṣṭau sīsakabhāgāḥ kāṁsasya dvau tu rītikābhāgaḥ ।
mayakathito yogaḥ ayam vijñeyo vajrasaṃghātaḥ ।।

A compound of eight parts of lead, two of bell-metal, and one of brass has been mentioned by *Maya* and is to be known as *vajra-saṃghāta*, a metal-joining cement.

This was possibly used in hot soldering of broken metallic parts of the idol, made of bronze or brass etc.

In a separate chapter (no. 50) on swords, entitled *khaḍgalakṣaṇam*, Varāhamihira provided some recipes about the hardening of steel which was called *śastrapāna* or 'sword-drink' (the word *śastra* had been used in *Yavanajātaka* to indicate steel). A sword rubbed with sesamum oil, and then smeared with an unguent prepared with the juice of the plant *arka* (*calotropis gigantea*), the gelatine from the horn of the sheep, and the excreta from the doves and mice, was to be given one of the 'drinks'; the steel pasted with oil and unguent was made red-hot in fire and then treated with one of the following: blood, *ghī*, water, milk of mammal animals or fish-bile. Then this had to be sharpened. (*Bṛ. Saṁ.*, 50. 23-25) Another process of heat-treatment was described as:

क्षारे कदल्या मथितेन युक्ते
दिनोषिते पायितमायसं यत्
सम्यक् शितं चाश्मनि नैति खड्ग
न चान्यलोहेषु अपि तस्य कौन्ठयम्
kṣāre kadalyā mathitena yukte
dinoṣite pāyitamāyasaṃ yat
samyak śitaṃ cāśmani naiti khaḍga
na cānyaloheṣu api tasya kauṇṭhayam
(*Bṛ. Saṁ.*, 50.26).

An iron weapon treated with a day-old drink made of the burnt powder of bananas (or its ribs) mixed with butter-milk, and then sharpened properly, will not break on stones, not become blunt on other instruments'.

Bṛhat Saṁhitā reveals that during its era, the metallurgical activity in the country was intense. Gold was tested, melted, heated in the fire, hammered for testing its purity, purified *nikaṣa santāpa abhiniveśaiḥ kanakasya eva adhikatara amalīkṛtasya* to make sacrificial ladles, thrones, images, etc. (*Bṛ. Saṁ.*, 26.9; 43.12; 47.46) Varāhamihira's statement shows that in India of his time, there

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were silver mines or *rajatākara* (*Bṛ. Saṁ.*, 16.26). Red-hot copper, evidently used for casting into various shapes, was referred to: *taptatāmraprabhābhaḥ* (6.13). References were made to the metal-smiths who fabricated weapons, and made a living working on fires:

> शस्त्रवार्ता: जीवन्ति च ये हुताशवृत्या
> *śastravārtāḥ jīvanti ca ye hutāśavṛtyā*
> (*Bṛ. Saṁ.*, 5.35 see also 5.28, 10.4, 85.29 etc.)

Archaeological evidences such as copper images of Buddha, Mehrauli iron pillar made during Candragupta II's reign etc., substantiate the literary claims about the advanced state of Indian metallurgy during the Gupta era. Even later, Vāṇa (seventh century AD) mentioned some of his companions as assayists and metallurgists. Hiuen-Tsang reported widespread use of noble metals and brass in India.

The two subjects of astronomy and mathematics were deeply pursued during the Gupta era. One of the outstanding scientists, Āryabhaṭa (born AD 476), emphasized on direct observations and only four elements, de-emphasizing the fifth: non-material *ākāśa*.

The *Padārtha-dharma-saṁgraha* of Praśastapāda was probably composed in the fifth century AD. It was more than a commentary on the *Vaiśeṣikasūtra* of Kaṇāda. This treatise gave a new exposition of the subject-matter and important additions to the original work. Chandra's *Daśa-padārtha-śāstra* is available only in the Chinese varsion of AD 648.

Praśastapāda described the formation of gross bodies from the atoms (*aṇu*) through dyads (*dvyāṇuka*) and the structural arrangement (*vyūha*) of the dyads to triads (*tryāṇuka*) which gives rise to different qualities in a substance. In *Praśastapāda-bhāṣya* was outlined the notion of impetus (*vega*) which accounts for continued motion of a body.

Some Buddhist scholars like Dignāga and Vasubandhu had questioned the *Vaiśeṣika* postulates on atoms. But others like Sarvāstivādin Śubhagupta, who flourished in the second century AD, defended atomism and the idea of a central atom combining with other atoms surrounding it. Dignāga had denied the existence of atom because it could not be separately perceived. Śubhagupta argued:

> न अणु आभासम् इति प्राहु:
> चित्त च एतसिकानां च सन्दिग्धता भवेत् एव
> *na aṇu ābhāsam iti prāhuḥ*
> *citta ca etasikānāṃ ca sandigdhatā bhavet eva*

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that in that case one had to doubt the existence of mind and the mental phenomena.as well!

The *Rasaśāstra* Texts

The Indian literatures on atomism provided at best a polemical ground and could not establish any viable link with the experimental discipline of *Rasaśāstra* or Indian alchemy, later developed into Iatro-chemistry. The *Rasaśāstra* tradition had its origin in *Atharvaveda*, the *Sāṁkhya* system and the Āyurvedic texts of Caraka and Suśruta. Through Nāgārjuna and other stalwarts, the subject evolved gradually, and gathered momentum after the seventh century AD. A chronological account of the relevant texts is summarised in Table 8.1.

Table 8. 1

Chronological Account of Principal *Rasaśāstra* Texts

(Dates Approximate)

600 BC	*Sāṁkhya* System of Philosophy, Kapila
500 BC	*Vaiśeṣika* System of Kaṇāda
400 BC	*Āyurveda* of Caraka and Suśruta (codified later)
300 BC	*Arthaśāstra* of Kauṭilya
200 BC	*Yoga* system of Patañjali. Also Yājñavalkya
1st century AD	*Saṁhitās* of Caraka and Suśruta codified
AD 50	Atomic theory of the Jainas
2nd century AD	*Nyāyasūtra* of Gautama and its commentary
AD 200	*Mādhyamika* Philosophy and *Rasaratnākara* (*RR*) of Nāgārjuna. Was *RR* in present form compiled later in the 7th-8th century AD?
AD 270	*Yavanajātaka* of Sphujidhvaja
4th century AD	Bower Manuscript of Ancient Medicine
5th century AD	*Kāmasūtra* of Vātsāyana; *Padārthadharmasaṁgraha* of Praśastapāda
AD 450	*Amarakośa* or *Nāmāliṅgānuśāsanam* of Amarsiṁha
AD 499	*Āryabhaṭīya* of Āryabhaṭa
AD 550	*Bṛhatsaṁhitā* of Varāhamihira
700-1300 AD : Tantric Period	
7th-8th century AD	Compilation of *RR*, the Buddhist text of Nāgārjuna (?)

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8th century AD	*Nidāna* of Mādhavācārya or Mādhavakara
800-850 AD	*Aṣṭāṅgahṛdaya* (*ASHR*) of Vāgbhaṭa
9th century AD	Probable date of *Sarveśvararasāyana* (*SSRS*) and *Dhātuvāda* (*DV*) of Nalina, later translated into Tibetan in 11th century AD.
AD 1000	*Siddhayoga* of Vrinda
AD 1019-1029	*Al-Bīrunī in India*
AD 1050	*Chakradatta* of Chakrapani Dutta

11th-13th Century AD : Safe Retreat of *Rasaśāstra* texts to Bhutan and Tibet

11th century AD	*Rasahṛdaya* (*RHR*) by Govindabhāgavat written at Kirataland or Bhutan (P.C. Ray thinks it could belong to 9th-10th century) *Rasārṇavakalpa* (*RNVK*)
12th century AD	*Rasārṇava* (*RNV*), a Hindu Tāntric text.
12th century AD	*Rasendracuḍāmaṇi* (*RCD*) of Somadeva

1300-1550 AD : Iatro-Chemical Period

13th century AD	*Rasaprakāśa Sudhākara* (*RPS*) of Yaśodhara
13th century AD	*Rasacintāmaṇi* (*RCM*) of Madanāntadeva
13th century AD	*Rasakalpa* (*RKP*), part of *Rudrayamala Tantra* (*RYT*)
Late 13th or Early 14th century AD	*Rasaratnasamuccaya* (*RRS*) of Vāgbhaṭācārya
14th century AD	*Rasajalalakṣmī* (*RJL*) of Viṣṇudeva
14th century AD	*Rasendra-Cintāmaṇi* (*RCT*) of Ḍhunḍhuknāth
14th century AD	*Rasendra-Sāra-Saṁgraha* (*RASASA*)
14th century AD	*Rasanakṣatramālikā* (*RNM*) of Mathanasimha
14th century AD	*Dhāturatnamalā* (*DRN*)
15th-16th century AD	*Rasapradīpa*
15th-16th century AD	*Dhātukriyā* or *Dhātumañjarī* (*DKM*), a part of *RYT*
15th-16th century AD	*Suvarṇatantra* or *Swarṇatantra* (*ST*)

The Indian alchemy revolved around two objectives: (i) the transmutation process for converting base metals (like lead, tin, mercury or copper) into the noble metals (gold and silver) and (ii) preparation of the 'Elixir of Life' for attaining immortality. The Indian alchemists pursued the above objectives in their laboratories, driven by superstitious premises.

Initially, the recipes of Patañjali, Caraka, Suśruta and the *Mahāyāna* mystic

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Nāgārjuna provided some impetus. After second century AD Indian alchemy came in contact with the Chinese tradition which believed in the efficacy of cinnabar or mercuric sulphide composed of *Yin* (female) and *Yang* (male) principles. The Indians adapted the Chinese idea, and evolved a Tāntric notion of alchemy by associating mercury with God Śiva's semen and sulphur with Goddess Pārvatī's menstrual discharge. Cinnabar became the symbol of the entire creation. Possibly the *Mahāyāna* Buddhists like Nāgārjuna and Asaṅga, who had access to both the Chinese (Taoist) and Indian (Tāntric) traditions, initiated the Tāntric variety of Indian alchemy, which gradually blossomed during the period AD 700-1300.

Around AD 1300, the *Rasavidyā* of India entered a more mature Iatro-chemical phase. Ray (1956:158) wrote:

> The fantastic and extravagant ideas, impossible of realisation, had subsided into something more practical and tangible. The numerous preparations of mecury, iron, copper and other metals, although they could not secure immortality or revive the dead, were found to be helpful accessories in medicine.

AD 1300-1600 period has been labelled as the era of Indian Iatro-chemistry during which many contacts were established with the Arab alchemy. During this period, the tradition of European alchemy was evolved mainly due to the efforts of Paracelsus (AD 1490-1541). The evolved Indian *rasaśāstra* texts such as *Rasaratnasamuccaya* described a number of chemical substances under the titles *mahārasas*, *uparasas*, *dhātus*, etc. and also several apparatus for synthesis and purification of these materials.

Many of these texts compiled old informations and added some newly derived laboratory data. We would omit the first category (old informations) and mention the relatively new acquisitions of knowledge pertaining to the non-gem minerals and metals.

The Texts of the Tāntric Alchemy Period (7th-13th Century AD)

We have already pointed out that the Mahāyāna Buddhist scholar, Nāgārjuna introduced alchemy during the second century AD. His *Rasaratnākara* text might have been amplified and re-edited during successive centuries. For nearly four centuries, the Hindu (Śaiva)-Buddhist (Mahāyāna) and Indo-Chinese cultural contacts resulted in Tāntric philosophy and mineral/metal-based medicines.

The medical treatise *Aṣṭāṅgahṛdaya* of Vāgbhaṭa (AD 800-850) mentioned

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widespread uses of minerals and natural salts like copper sulphate, red ochre, realgar, orpiment, iron sulphate, etc. in external applications for sores. The idea of cauterisation of wounds by alkalis was borrowed from Suśruta. There were only a few examples of mercury salt therapy which was evidently not widespread in its use.

Nidāna of Mādhavācārya or Mādhavakara might have been composed in the eighth century AD (or ninth, according to another view). *Nidāna* was one of the medical treatises translated by the order of the Caliphs.

Sarveśvararasāyana (*SSRS*) and Nalina's *Dhātuvāda* (*DV*) were probably composed during the ninth century AD, and translated into Tibetan two centuries later. (Bhattacharyya, 1932; Ray, 1956: 123-24) *SSRS*, 5 described the reaction between copper and sulphur to produce copper sulphide. The art of purifying *raṅga* or tin was known (*SSRS*, 6) *Dhātuvāda* described the preparations of gold-silver-lead alloy and copper amalgam using copper and quicksilver (*DV*, 4-5).

Dhātuvāda described a process of coating iron with metallic copper. Plant ash (potassium salt) and sour wine (vinegar or acetic acid) when kept in a copper vessel gives a 'paint' (solution containing copper acetate) which when applied on iron gives a deposit of copper (*DV*, 2-3; Ray, 1956:144 and 452). This is the first Indian reference to the hydrometallurgical route of making copper, using the displacement reaction with iron:

$$Cu^{2+} + Fe^{o} \rightarrow Cu^{o} + Fe^{2+}$$

(Solution) (Metal) (Metal) (Solution)

In a well-researched paper, T.N. Lung (1986) has documented that China was the first nation to discover the above cementation route to make copper from the mine water and vitriol spring containing cupric ion in solution. Several records on the process were written during the period second century BC to second century AD. One Eastern Han Period (AD 25-220) recipe actually used vinegar antedating Nalina's process mentioned in his *Dhātuvāda*. Commercial production of cement copper started in China around AD 1086. It is quite possible that the reference in *Dhātuvāda* on cementation of copper indicated India's scientific-cum-technological contact with China through Tibet.

Ever since the days of Vāgbhaṭa the medicinal use of metallic preparations went on increasing. This was witnessed and recorded by Al-Biruni. Vrinda's *Siddhayoga* (AD 1000) mentioned many metallic preparations such as 'killed' or oxidised iron, killed copper, a *Nāgārjuna-varti*, the reaction product of copper and sulphur : *parpatītāmram*, of mercury and sulphur: *rasāmrta-cūrṇam*, etc. Vrinda recorded that

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नागार्जुनेन लिखिता स्तम्भे पाटलीपुत्रके
nāgārjunena likhitā stambhe pāṭaliputrake
(*Siddhayoga*, LX. 148-149)

Such recipes suggested by Nāgārjuna were written on pillars at Pāṭalīputra.

Similarly Cakrapāṇi Dutta mentioned in his *Cakradatta* (AD 1050) the medicinal uses of killed iron, *mandura* or the rust of iron, *raupyamal*, the calx of silver, *kajjali* or mercuric sulphide and *tāmrayoga*, a product of sulphur and copper from Nepal. He also formulated a depilatory soap to be made by saponifying mustard oil with plant ash (potassium carbonate) and lime.

The Indian contact with Tibet had begun several centuries earlier but this culminated with the migration of Dipāṅkara or Atisa (AD 980-1053), the famous Buddhist monk of Udandapura and Vikramasila. These famous monasteries were destroyed by Muslim invaders in the twelfth century, and by that time many Buddhist and alchemical texts had been safely transported to Bhutan and Tibet.

Govindabhagavat wrote *Rasahṛdaya* (*RHR*) in the eleventh century AD at the request of the king of the Kirataland, i.e., the region adjoining the modern Bhutan. He mentioned eight *rasas* including *vaikrānta* (tourmaline?), *kānta* (a kind of iron); eight *uparasas* such as *kankustha* (magnesium and sodium sulphate, a purgative); six salts including *sauvarchala* (saltpetre), *chulika* (sal ammoniac), *romaka* etc.

A special feature in *Rasahṛdaya* text is the description of eighteen steps for purification of mercury in an apparatus like *dipikā yantra* (*RHR*, 1.1-8). It was stated that pure copper, amalgamated with mercury, when subjected to heat and distillation (*pātana*), produced pure mercury freed from lead and tin impurities (*RHR*, 1.8). Also described were various processes of 'killing' mercury with sulphur (*RHR*, 16.11-13). Orpiment or a mixture of sulphur and mica (*RHR*, 3.19-23). *Abhra* was probably a sulphide mineral with metallic lustre sometimes mistranslated as a 'mica'.

Another worth-mentioning text written in the eleventh century AD is *Samarāṅgana-Sūtradhāra* of Bhoja, the Paramāra ruler of Dhārā (AD 1000-1055). This work on medieval Indian architecture dealt, in its eighth chapter, with the examination of the earth and the varieties of its clay prior to building (8.02-8.77). Chapter 29 described beautification of seats, chairs, etc. with gold, silver, bell metal, brass (*ārakūṭa*, 29.06) and gems. Bhoja mentioned the property of phosphorescence exhibited by diamond, shining in the dark.

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In the twelfth century AD, Somadeva culled his materials for *Rasendracūḍāmaṇi* from the pre-existing chemical treatises. He mentioned an alloy made of copper, tin, zinc and lead. Lead and tin metals when 'killed' were known as *capala* (quick-flowing), because on heating, these 'resurrect' quick-flowing or low-melting metals. Somadeva mentioned antimony as a metal (*varanāga*-lead like) and its preparation:

> तीक्ष्णं नीलान्जनोपेतं ध्मातं हि बहुशो दृढ़म्।
> मृदुकृष्णं द्रुतद्रावं वरनागं तदुच्यते।।
> *tīkṣṇaṃ nīlāñjanopetaṃ dhmātaṃ hi bahuśo dṛḍham ।*
> *mṛdukṛṣṇaṃ drutadrāvaṃ varanāgaṃ taducyate ।।*
>
> *Nilāñjana* (stibnite), mixed with *tīkṣṇam* (cast iron) and strongly heated several times, yields a superior kind of lead, which is readily fusible and is of mild black colour.

Rasaratnasamuccaya (8.98) reported that Somadeva had compiled the technical terms from different texts 'like the jewels from the ocean'.

Rasārṇava — A Brāhmaṇical *Tantra*

Many of the early *Rasaśāstra* texts had been composed by the *Mahāyāna* Buddhists who maintained close links with the Brāhmaṇical tradition of *Tantra* and the Śiva-Pārvatī cult. With the flight of Buddhist monks and demolition of monasteries by the Muslim invaders, the Brāhmaṇical texts like *Rasārṇava* (*RNV*) of the twelfth century AD became very important.

Rasārṇava described a large number of equipment or apparatus, crucibles, furnace, etc. for processing of minerals,and metals. (Ray and Kaviratna, 1910, 1985) *Dolayantram* for example was an apparatus for steam-heating of suspended solids. Crucibles were made of different kinds of earth, iron-rust and burnt husks of paddy. Covered crucible resembled the nipple of a cow and were fitted with lids having raised heads. The flames were stated to be specifically coloured due to specific salts of copper, tin, lead, etc. (*RNV*, 49). The characteristic of molten pure metal in a crucible was described:

> न विस्फुलिंगा न च बुद्बुदाश्च यदा न रेखापटलं न शब्दः।
> मूषागतं रत्नसमं स्थिरश्च तदा विशुद्धं प्रवदन्ति लोहम्।।
> *na visphuliṅgā na ca budbudāśca yadā na rekhāpaṭalaṃ na śabdaḥ ।*
> *mūṣāgataṃ ratnasamaṃ sthiraśca tadā viśuddhaṃ pravadanti loham ।।*
>
> (*RNV*, 52-55)

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> A pure metal is that, which when melted in a crucible, does not give off sparks nor bubbles, nor spurts, nor emits any sound, nor shows any lines on the surface, but is tranquil like a gem (shows signs of tranquil fusion).

Procedures were described for making copper metal from *mākṣika* (*RNV*, 7.12-13), *vimala* (7.20-21) *sasyaka* (7.41-44) etc., the first two are pyrites bearing copper, and the third copper sulphate. The red copper metal was compared with coccinella insect: *indragopasaṅkāśam sattvam*. *Rasārṇava* repeated Nāgārjuna's recipe for making zinc (from calamine or *rasaka*) the metal which is 'like tin and converts copper to gold' (actually to brass):

> सत्वं कुटिलसंकाशं
> करोति शुल्वं त्रिपुटेन कांचनम्।।
> *satvaṃ kuṭilasaṃkāśaṃ* ।
> *karoti śulvaṃ tripuṭena kāñcanam* ।।
> (*RNV*, 7.34-38)

Zinc ore (*rasaka*) was stated to impart gold-like colour to copper as well as lead and iron (*RNV*, 12.50). Preparation of a copper-zinc-lead alloy was described (*RNV*, 17.70-74).

Six metals were arranged in the order of increasing rate of corrosion:

> सुवर्णं रजतं ताम्र तीक्ष्ण वंग भुजंगमा:।
> लोहकं षड़िधं तच्च यथापूर्वं तदक्षयम्।।
> *suvarṇam rajataṃ tāmra tīkṣṇa vaṅga bhujaṅgamāḥ* ।
> *lohakaṃ ṣaḍidhaṃ tacca yathāpūrvaṃ tadakṣayam* ।।
> (*RNV*, 7.89-90)

High reactivity of sulphur with most of the metals was described poetically: 'There is no such elephant of a metal which cannot be killed by the lion of a sulphur or pyrites'.

> नास्ति तल्लोहमातंगो यन्न गन्धककेशरी।
> निहन्यात् गन्धमात्रेण यद्वा माक्षिककेशरी।।
> *nāsti tallohamātaṅgo yanna gandhakakeśarī* ।
> *nihanyāt gandhamātreṇa yadvā mākṣikakeśarī* ।।
> (*RNV*, 7.142)

Metals were reported to be 'killed' (*jārana*) by materials like *kāsīsa* (green vitriol), *sauvira* (stibnite), *sauvarcala* (saltpetre), etc. (*RNV*, 9.2-3).

Rasārṇava mentioned three kinds of *kṣāra* or alkali: *tankaṇa* or borax,

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yavakṣāra (carbonate of potash in the ash of barley) and *sarjikā* or river bed sodium carbonate/bi-carbonate (5.35-36). Eight *mahārasas* (*RNV*, 7.2-3) included *srotāñjana* which was probably copper/antimony/cobalt sulphide, found on the banks of river and later colloqually known (in Rajasthan) as *sohtā*.

Iatro-Chemical Texts

In the words of Ray (1956:158) the iatro-chemical period in India started in the thirteenth century AD after 'the fantastic and extravagant (alchemical) ideas, impossible of realization, had subsided into something more practical and tangible'. We would end this chapter by mentioning three thirteenth century iatro-chemical texts; in the next chapter we would present the most important text of this category, *Rasaratnasamuccaya* which belongs to early fourteenth century AD.

In *Rasaprakāśaśudhākara*, Yaśodhara described, probably for the first time in India, the preparation of *karpūrarasa* or calomel. To be made by heating mercury with common salt, alum and borax, calomel or mercuric chloride was recommended as an aphrodisiac and for leprosy.

Alum from Saurāṣṭra, known as *tuvari* was popular as mordant for dyes. When slightly yellow, it was known as *phullika*. The material could 'kill' iron.

Two varieties of *rasaka* or calamine were known: *karavellaka* and *dardura*. The process of extracting zinc from calamine was described; this was almost identical with that noted in *Rasaratnasamuccaya*. The essence (*sattva*) of *rasaka*, that is zinc metal, was a reduction-cum-distillation product like *rasa* (mercury), and hence the name *rasaka*. It possessed the lustre of lead.

तदा सीसोपमं सत्वं पतत्येव न संशयः।
tadā sīsopamaṃ satvaṃ patatyeva na saṃśayaḥ ।

The crucible used was like a brinjal *mūṣām vṛntākaphalasannibhām*. Nāgārjuna's authority was invoked to proclaim that both mercury as well as zinc salts are supposed to strengthen the body:

पारदो रसकश्चैव देहलोहकरावुभौ।
pārado rasakaścaiva dehalohakarāvubhau ।

Madanāntadeva mentioned in his *Rasacintāmaṇi* the preparation of calomel, but named this as *śvetabhasma* instead of *karpūrarasa*. He referred to an alloy made of bell-metal, silver and cast iron. Copper, made from blue vitriol or *tutthaka*, was named as *tutthaka-sattva* or the 'essence' of blue vitriol.

The process of making zinc (*kharparasattvapātana*) from calamine (*kharpara*),

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described in *Rasacintāmaṇi* was similar to the one formulated by Yaśodhara, with one difference. Whereas Yaśodhara hits off the completion of reduction when the flame issuing from the pot ceases to be blue, Madanāntadeva directs that 'the pot is to be taken out of the furnace, soon as white fumes begin to appear. The crucible is then to be held in an inclined position so that the lead-like essence of calamine drops on the ground'.

Rasakalpa, which is a part and parcel of *Rudrayamala Tantra*, also belonged to the thirteenth century AD. The author has restricted his treatise solely to a description of the metals, minerals, and the process of 'killing' them with the agency of various apparatus.

Rasakalpa mentioned *mahārasas*, *uparasas* and *rasas*. It referred to *culikālavaṇa* (sal ammoniac) used as a *viḍa* for killing gold. There were two kinds of *tāla*, *tālakaṃ dviprakāraṃ syāt godantaḥ pāṭalacchaviḥ* two kinds of *gairika*, one of golden blue, the other red. There were different kinds of *saurāṣṭrīs* or alums and three kinds of *kāsīsas* (green and other vitriols):

बहुप्रकारा सौराष्ट्री कासीसं त्रिविधं मतम्।
कासीसं पुष्पकासीसं हीरकासीसमित्यथ।।
bahuprakārā saurāṣṭrī kāsīsaṃ trividhaṃ matam ।
kāsīsaṃ puṣpakāsīsaṃ hīrakāsīsamityatha ।।

The vitriols ranging from blue copper sulphate to green ferrous sulphate were variously known as *tutthaka*, *sasyaka* and *kāsīsa*. *Rājāvarta* mentioned as a *rasa* has been translated as *lapis lazuli*, a rare gem coloured blue; it could actually be a blue copper mineral.

Processes were described for extraction of copper from *mākṣika* (copper bearing pyrite), and of zinc from calamine involving distillation through *vakranāla* or bent tube. *Vartaloha* was mentioned as an alloy : *vartādyāḥ syustu kṛtrimāḥ*.

The composition was not mentioned. Later *Rasaratnasamuccaya* (*RRS*) (5.212) mentioned that *vartaloha* was composed of bronze, copper, brass, iron and lead, and hence also known as *pañcaloha*.

We would discuss in the next chapter how *RRS* beautifully summarised the diverse technical data in the *Ratna-* and *Rasaśāstra* texts.

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9

Rasaratnasamuccaya — A Pinnacle in the Indian Iatro-Chemistry

THE ancient or Hindu period in Indian history is supposed to have ended around twelfth century AD with the onset of Muslim influence in the sub-continent. However, the writing of Sanskrit texts continued even after this date. An early fourteenth century compilation — *Rasaratnasamuccaya* (hereafter abbreviated as *RRS*) — would be the terminal point in our discussion, even though some more iatro-chemical texts appeared after *RRS*. (Ray, 1956:158-207)

Technical Terms Related to Mineral and Metal Processing

Sri Vāgbhaṭa compiled in *RRS* many details regarding gems, non-gem minerals, metals, alloys, metallic transformations (*lohavedha*) and the transformations of body tissues (*dehavedha*). For the conversion of minerals to a pharmaceutical recipe, acceptable to the body, several steps had been envisaged: purification (*śodhana*), incineration (*māraṇa*), metallic extraction (*satvapātana*), liquefaction (*druti*), etc.

Śodhana by acidic (*amla*) and/or alkaline (*kṣāra*) material (8.59-8.60) was designed to remove the toxic material. *Satva* was defined as the metallic extract:

> क्षार अम्लद्रावकयुक्तं ध्मातम् आकरकोष्ठके।
> यस्ततो निर्गतः सारः सत्वम् इति अभिधीयते।।
> *kṣāra amladrāvakayuktaṃ dhmātam ākarakoṣṭhake ।*
> *yastato nirgataḥ sāraḥ satvam iti abhidhīyate ।।*
>
> (*RRS*, 8.34)

White flame at the time metal is released is called *śuddhāvarta*:

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शुद्धावर्तस्तदा ज्ञेयः स कालः सत्वनिर्गमे।
śuddhāvartastadā jñeyaḥ sa kālaḥ satvanirgame ।
(*RRS*, 8.56)

Bījāvarta is the characteristic colour of flame when the metal produced is about to melt (8.57). The metal could be cooled in the furnace (*swāṅga śīta*) or outside, *bahiḥśīta* (8.58).

Māraṇa means killing or oxidation of metal from which metal can be regenerated (*utthāpana*) (8.39). If the metal is oxidised irreversibly, then it is called *apunarbhava* (8.29). Removal of a metallic impurity by blowing through a bent pipe (*vaṅkanāla*) in a way it is converted to an oxide scum is called *tāḍana* (8.32).

Ḍhālana meant pouring of molten metal. *Capala* meant easy-melting oxide of lead or *nāga*, tin or *vaṅga*, etc. (8.41-8.44).

The concepts of alloy (*miśraloha*) and heat-treatment were first put into literature by Somadeva in his *Rasendra Cūḍāmaṇi*, and *RRS* followed Somadeva. *Nirvāpana* or *nirvāhana* was defined as the art of putting one metal into another through *vaṅkanāla* (8.24-8.25). This was probably practised by introducing zinc vapour into molten copper to make brass. Addition of foreign substance to molten metal was also known as *āvāpa* or *prativāpa* (8.52).

Two different procedures of quenching were described. *Abhiṣeka* meant pouring of water all around on a (molten) metal. Dipping of hot metal in liquid or water was known as *nirvāpa* or *svapana*:

सलिलस्य परिक्षेपः सः अभिषेकः इति स्तुतः।
तप्तस्य अप्सु विनिक्षेपो निर्वापः स्वपनं च तत्।।
salilasya parikṣepaḥ saḥ abhiṣekaḥ iti stutaḥ ।
taptasya apsu vinikṣepo nirvāpaḥ svapanaṃ ca tat ।।
(*RRS* 8.53-54)

Some of the technical terms were specifically related to mercury. This liquid metal was purified by *pātana* or distillation, which involved 'movement of vapour upwards, downwards and obliquely from the distillation equipment and thus removal from impurities such as tin and lead':

मर्दित पारदस्य यन्त्रस्थितस्य
उर्ध्वं अधश्च तिर्यक्।
निर्यातनं पातनं संज्ञं उक्तम्
वंगाहि सम्पर्क कंचुकघ्ननम्।।

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mardita pāradasya yantrasthitasya
urdhvaṃ adhaśca tiryak ।
niryātanaṃ pātanaṃ saṃjñaṁ uktam
vaṅgāhi samparka kañcukaghnanam ॥
(*RRS*, 8.64)

Mercury used to be converted to oxide or sulphide or solid amalgam 'in which fluidity was lost' (*naṣṭa piṣṭa*). *Viḍa* was the treatment with *kṣāra*, *amla*, *gandhaka*, *lavaṇa*, etc. prior to *grāsa* or *jārana*, or amalgamation of metal with mercury (8.67, 8.84). *Vedhana* or transmutation of base metals to silver or gold was expected by pasting mercury (*lepa vedha*) on the base metal, or by putting mercury into the molten base metal (*kṣepa vedha*). Iatro-chemistry had not yet snapped its extravagant alchemical roots.

RRS contains a wide-ranging list of implements and equipments to be used in the alchemical laboratory (chapters 5 and 7). Several kinds of crucibles and furnances (*mūṣā, koṣṭhi, puṭa*) were described (chapters 5, 9 and 10). The author, Śrī Vāgbhaṭa, openly acknowledged that his predecessor, Somadeva had collected most of the technical terms and their lucid descriptions from the earlier texts of *Rasaśāstra*, and thus 'prepared a garland of jewels to be worn in an assembly of scholars':

स्फुटतर परिभाषानाम् रत्नानि हुत्वा . . .
. . . कन्ठमालाम् . . . मन्डनार्थ सभायाम्।
sphuṭatara paribhāṣānām ratnāni hutvā . . .
. . . kanṭhamālām . . . . manḍanārtha sabhāyām ।
(*RRS*, 8.98)

Gem Minerals

In one of our previous chapters (chapter 7) we have mentioned the references to *ratna* or gem minerals in *RRS* (chapter 2), which is indeed an unique compilation (*samuccaya*) of *rasa* — as well as *Ratnaśāstra* text materials. Here we would merely emphasize that *RRS* believed the gem minerals to be potential sources of medicine. Hard minerals for example, when suitably administered, were believed to make the human tissues strong. Combined with mercury, precious stones could become medicines. This was another alchemical belief.

Emerald was known as *tārkṣya*, *garuḍodgāra*, etc. Cat's eye gem was called *viduraka*. Diamond was known as *vajra* as well as *bhidura*. Diamond was classified under three 'genders': masculine, feminine and neutral as well as under four conventional castes (*RRS*, 4.26-4.30).

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Vaikrānta has been described (*RRS*, 2.53-2.60) as 'possessing eight edges, eight facets, six angles, smooth and heavy, associated with one or more of eight kinds of colours, occurring around Vindhya, able to cut down or deform the metals':

विकृन्तयति लोहानि तेन वैक्रान्तकः स्मृतः
vikṛntayati lohāni tena vaikrāntakaḥ smṛtaḥ
(*RRS*, 2.60)

The above description reminds us of a similar one for diamond (4.27), and it is possible that *vaikrānta* of *RRS* was indeed diamond of different colours. However the reference to *satvapātana* of the gem or extraction of metal from it (2.69-2.71) makes us wonder whether the name was also applied to some other hard mineral containing iron (magnetite) or manganese. Many authors have translated *vaikrānta* as tourmaline.

Eight *Mahārasas*

RRS has named eight *mahārasas*: *abhraka* (mica), *vaikrānta*, *mākṣika* (pyrites), *vimala* (iron pyrite), *adrija* (bitumen), *sasyaka* (blue vitriol), *capala* (bismuth or lead or tin ores yielding quick-melting metals) and *rasaka* (zinc ore). These were recommended for 'collection after identification' (2.1).

Abhraka, tentatively translated as mica, was defined as a class of material which binds mercury, and therefore these materials were probably sulphur-bearing mica-like substances. *Abhrakas* were classified in *RRS* under four categories depending upon their colours and behaviours when put on fire.

Pināka variety of *abhraka* was described as white and 'setting free its *dalas* or folds' when put on fire:

पिनाकं पावकोत्तप्तं विमुंचति दलोच्चयम्
pinākaṃ pāvakottaptaṃ vimuñcati ḍaloccayam
(*RRS*, 2.5)

The material could be vermiculite which indeed swells (due to expansion of water-rich lattice and elimination of water molecules) when put on fire.

Nāga variety of *abhraka* is red and 'produces hissing sound like that of snake when put on fire'.

नागाभ्रं नागवत् पावकं संस्थितम्
nāgābhraṃ nāgavat pāvakaṃ saṁsthitam
(*RRS*, 2.6)

The material could be red lead or, if the colour is not red, even mica-resembling

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galena; these produce, on reduction, lead or the metal known as *nāga* or *ahi*. *Maṇḍūka* variety is yellow, bursting into fragments when put on fire. *Vajra* variety of *abhraka* is black and does not change when put on fire (2.7-2.8). It was believed that yellow mica could produce gold, and white mica could produce silver through reaction with mercury (*RRS*, 2.9-2.10). This belief led to elaboration of the procedures for *satvapātana* (metal-extraction) from *abhraka* (2.27-2.38).

We have already mentioned *vaikrānta* which was known both as a gem as well as one of the *mahārasas*. *Mākṣika* was known to occur in two varieties:

माक्षिको द्विविधो हेममाक्षिक स्तारमाक्षिक:
mākṣiko dvividho hemamākṣika stāramākṣikaḥ
(*RRS*, 2.81)

Hemamākṣika or gold-coloured *mākṣika*, occurring around Kānyakubja, Tāptī river, etc., was most probably copper pyrite or chalcopyrite which could be reduced by organic materials such as *sneha gavyājya* (cow's *ghī* or butter-fat) to produce the red metal, copper (2.85-2.89). *Tāra mākṣika* looked silvery and was probably iron pyrite.

Vimala also represented pyrite-group minerals and sulphides. There were *hema* and *tāra* varieties as in *mākṣika*, and these were probably the same as chalcopyrite and pyrite. A third variety *kāṁsya vimala* has been identified as arsenopyrite. Another particular variety, most probably galena, was described (2.96-2.102) as 'cubic in shape, having angles and facets, brilliant, reducible by borax and charcoal to yield *sīsaka*-type metal':

वर्तुल: कोणसंयुक्त: . . .
षट्प्रस्थकोकिलै धर्मातो विमल: . . . सीससन्निभ:
vartulaḥ koṇasaṃyuktaḥ . . .
ṣaṭprasthakokilai dharmāto vimalaḥ . . . sīsasannibhaḥ

Śilājatu or bitumen was known to be an exudate from the lower part of the Himālayas. It could be *sasatva* (with metallic content) or *niḥsatva* (without any metallic content) (2.109).

Sasyaka or blue vitriol was likened to the blue neck of a peacock (2.125). *Rājanighanṭu* commented that *sasyaka* is a natural material, while *tuttha* or *tutthaka* (copper sulphate) is artificially prepared. "In the absence of one, the other may be used". The chemical identity of the two was not firmly established. Similarly, while describing *satvapātana* or metal extraction from *sasyaka* by reduction-heating in a crucible, the identity of the red metal 'looking like *indragopa* or coccinella insect' with copper was guessed but not confidently affirmed (*RRS*, 2.133-2.134):

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इन्द्रगोपाकृति चैव सत्वं।
ताम्ररूपं सत्वं मुंचति सस्यकम्।।
indragopākṛti caiva satvaṃ ।
tāmrarūpaṃ satvaṃ muñcati sasyakam ।।

Capala was defined as a material which melts quickly like *vaṅga* or tin when put on fire *vaṅgavad dravate vahnau capalastena kīrtitaḥ* (*RRS*, 2.143) and has six edges, brilliance and heaviness. *Capala* could be yellow, white, red or black. Was the heavy black variety galena, yielding low-melting metal lead? As a matter of fact, *RRS* does refer to *nāgasambhūta capala*, or lead-bearing *capala* (8.41-8.42) and *vaṅgasambhūta capala*, another variety containing tin (8.43-44). Some scholars have claimed that a third variety of *capala* contained bismuth.

Details about *rasaka* or zinc blende would be mentioned later in connection with zinc metallurgy.

Uparasa Materials

Eight drugs of *uparasa* group, useful in *pāradakarma* or fixation of mercury, were stated to be: *gandhāśma* or *gandhaka* (sulphur), *gairi* (red ochre), *kāśīsa* (ferrous sulphate), *kāṅkṣī* (alum), *tāla* (orpiment), *śilā* (realgar), *añjana* (collyrium) and *kaṅkuṣṭha* (rhubarb) (*RRS*, 3.1).

Four varieties of sulphur were known: red or *śukacancunibha*, yellow or *śukapiccha*, white variety, good for reaction with iron, and black sulphur which may be used as an anti-bacterial medicine. Sulphur was purified by boiling or melting in milk and filtration (3.20-3.22).

Gairika (red ochre) could be deep red (*svarṇa gairika*) or copper-coloured (*pāṣāṇa gairika*) (*RRS*, 3.46-3.48). An earlier scholar Nandi was quoted to say that *gairika* is itself a *satva* or metal. *RRS* quoted dissenting scholars saying that *satva* (iron) can be obtained from *gairika* (iron oxide) (3.49).

Kāśīsa (ferrous sulphate) could be of two varieties: *puṣpakāśīsa*, which imparts black colour to hair and removes pimples (*vraṇāghna*), and *bālukākāśīsa* which looks like *aguru-dhuma* and is either alkaline or acidic in solution.

क्षाराम्लागुरुधूमाभं
kṣārāmlāgurudhūmābhaṃ
(*RRS*, 3.52)

We know that ferrous sulphate hydrolyses, and the solution is not neutral.

Tuvarī or alum used to be obtained from the mountain rocks of Saurāṣṭra. This was widely used as a mordant to bind and deepen the colour of a dye such

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as *mañjiṣṭha* (*RRS*, 3.59). Two varieties were recognised: slightly yellow, heavy and brilliant *phaṭakī* or *pītikā*, and white, light and *amla* or sour in taste, *phullikā*. The latter was known to react with copper sheets (*RRS*, 3.61-62) indicating the reactivity of copper with the sulphate ion from alum. *Kāṅkṣī* described as *kaṣāya* or astringent is also alum.

Tālaka/tāla / haritāla (orpiment) could be of two types: many-layered, golden coloured, heavy, brilliant *patra tālaka*, and massive *piṇḍa tālaka* containing less *satva* or pale yellowish metal (*RRS*, 3.76-77).

Manaḥśilā or realgar came under three varieties: yellowish red, heavy *śyāmāṅgī*, copper-red *kaṇavīraka* like *kaṇavīra* or *karavī* flower and deep red, heavy *khaṇḍākhyā* which contains more metal (3.89-90).

Five varieties of *añjanas* or collyrium were described: *sauvirāñjana*, *srotāñjana*, *nīlāñjana* which were antimony sulphide, carrollite (copper-cobalt sulphide) etc.

Navasāra, also known as *cullikā lavaṇa* was produced by burning shoots of bamboos, or pilu woods. Typified as a *kṣāra* or alkali (3.127-129) it was likely to contain potassium carbonate and potassium chloride; Ray (1956:176) claimed this to be sal-ammoniac or ammonium chloride but confessed that 'sal-ammoniac, however, cannot be an alkali'.

Identity of some of the cited minerals could not be firmly established: *Kaṁpillaka* from Saurāṣṭra, which looks like brick powder, 'white or quartz-like *gaurīpāṣāṇa* which yields a white *satva*', yellow marine nodules *varāṭikā*, *girisindūra* 'inside rocks of big mountains which becomes red on drying', etc.

Mṛddāraśṛṅga was probably litharge or lead monoxide from which lead could be extracted. It 'came from Gurjara province near the Arbuda mountains, coloured yellow with lamellae yielding lead and used as a hair-tonic'

सदलं पीतवर्णं गुर्जरमण्डले
अर्बुदस्य गिरेः पार्श्वे जातं
मृद्दारशृंगकम् सीससत्वं केशरं जनमुत्तमम्।।
sadalaṃ pītavarṇaṃ gurjaramaṇḍale
arbudasya gireḥ pārśve jātaṃ
mṛddāraśṛṅgakam sīsasatvaṃ keśaraṃ janamuttamam ।।
(*RRS*, 3.146)

Hiṅgula/darada or cinnabar was known to occur in two varieties: inferior grade *śukatuṇḍa* and white-lined, coral-like *haṁsapāka* (*RRS* 3.139).

Hiṅgula when distilled, released its *satva* 'which is definitely like *suta* or

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mercury, and has the property of the material which is fixed by sulphur'

दरद: पातनयन्त्रे पातितश्च जलाश्रये
तत् सत्वं सुतसंकाशं जायते नात्र संशय:
एतस्मादाहुत: सुतो जीर्णगन्धसमो गुणै:
daradaḥ pātanayantre pātitaśca jalāśraye
tat satvaṃ sutasaṃkāśaṃ jāyate nātra saṃśayaḥ
etasmādāhutaḥ suto jīrṇagandhasamo guṇaiḥ
(*RRS*, 3.141 and 3.144)

It may be noted that the author fell short of saying that the metal obtained from mercuric sulphide was mercury itself — merely stated the close resemblance between the two. As a matter of fact, the metal extracted from *hiṅgula* in an apparatus like *vidyādhara* or *ḍamaru yantra* was called *hiṅgulākṛṣṭa* and not *rasa* or mercury (*RRS*, 8.37 and 9.56-57). Probably it was believed that the property of the end-product (metal) was dependent on the raw material from which it was extracted.

For the metallurgical practices, special crucibles were made for which specific raw materials were necessary. *Toyamṛttikā*, a water-proof paste was made by mixing fine powder of *maṇḍūra* (rusted iron), *guḍa* (molass), *cūrṇa* (limestone) and watery extract of *acacia indica*; crucible made of this paste was fired before use. *Vahnimṛttikā* or fire-clay crucibles and seals were made using *khaḍiā* (chalk), *lavaṇa* (salt), *maṇḍūra* (iron rust), milk, etc. This resists intense heat and is impervious to mercury-liquid and as well as vapour. 'Mercury sealed by this mixture, known to Nāgārjuna, Nandi, Somedeva etc., cannot escape, just like a man bound with an ardent love of a mature lustful lady' (*RRS*, 9.64).

एतया मृत्स्न्या रुद्धो न गन्तुं क्षमते रस:।
विदग्ध वनिता प्रौढ़ प्रेम्ना रुद्ध: पुमानिव।।
etayā mṛtsnyā ruddho na gantuṃ kṣamate rasaḥ
vidagdha vanitā prauḍha premnā ruddhaḥ pumāniva ।।

In the tenth chapter of *RRS*, different kinds of *lavaṇa* (salt), *kṣāra* (alkali), *amla* (acidic liquids) were mentioned. We have stated them in the previous chapters. *RRS* mentioned that:

क्षारा: सर्वे मलं हन्यु: अम्लं शोधनजारणम्
kṣārāḥ sarve malaṃ hanyuḥ amlaṃ śodhanajāraṇam
(*RRS*, 10.96)

All the alkalies destroy impurities and the acids are used for *śodhana* (purification) etc.

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Many specific plant and animal products such as *taila* (oil), *vasā* (fat), etc. were mentioned and used as reductants, with the belief that they played specific roles, apart from serving the general purpose of reducing minerals to metals in a furnace.

Organic and inorganic fluxes (such as *ṭaṅkaṇa* or borax), called *drāvaṇa*, were used 'to aid in the melting of metals which are otherwise difficult to melt', i.e., to lower the fusion point:

दुर्द्राव अखिल लोहादेः द्रावणाय गणो मतः
durdrāva akhila lohādeḥ drāvaṇāya gaṇo mataḥ
(*RRS*, 10.95)

Some Salts and Natural Products

Ray (1956: 201-32) has commented on some of the terms related to salts and natural products mentioned in the *Rasaśāstra* texts including *RRS*, and we may summarise these comments.

Romaka has been described: 'also called *Śākāmbarī*, is the salt produced from the Sambar Lake near Ajmer'. We however believe that this was some material imported from the Roman empire.

Audbhida has been identified by Ray (1956: 204) as the saline deposit *reh* obtained as an efflorescence, containing chloride and sulphates of sodium. But this *reh* has always been known in India as *sarjikā mṛttikā* or *sājimāṭi*. *Audbhida* was most likely the potassium-containing ash from the plants (*udbhida*), which also contained chlorides to 'kill' mercury.

Viḍa/viṭ or black-salt probably used to be prepared by fusing common salt with sodium sulphate or *sājimāṭi* and organic materials like the fruit of *T. Chebula*. The reddish brown colour of *viḍa* is due to reduction of the sodium sulphate to sulphide which converts the iron impurity (this as well as sulphate come from the common salt) to the coloured sulphide. The material was used medicinally to aid digestion. (Ray, 1956: 205)

Sauvarcala stands for saltpetre in *Rasārṇava* and other *Rasa* texts. Its use in fireworks or *Yogavartikā* was mentioned by Daṇḍī (sixth century AD) in his *Daśakumāracarita*. It occurred extensively as an efflorescence on the soil in North India. There is a seventeenth century description of its preparation at Ajmer by lixiviation of the soil, evaporation and crystallisation. (Ray, 1956: 229)

Alum has been known as *saurāṣṭraja* (from Saurāṣṭra or Sūrat), as well as *kāṁkṣī* and *tuvarī*. Ferrous sulphate was known as *kāśīsa* and copper sulphate as *sasyaka*. These alteration products originated from rocks and mines. Several

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nineteenth century literatures described their manufacture (in Cutch, Rajasthan, etc.) by successive operations of lixiviation, evaporation and crystallisation. (Ray, 1956: 230-33) Similar processes must have existed earlier for many centuries.

Kaṁkuṣṭham was possibly an efflorescence of magnesium and sodium sulphate occurring at the foot of the Himālayas (*RRS*, 3.109). The yellow colour was due to admixture with ferruginous dirt. This material was used as a purgative. (Ray, 1956: 201)

Metals and Alloys in *RRS*

Rasaratnasamuccaya (*RRS*) provided a definition and classification for the metallic systems. The word metal or *loha* was defined as

धातुर्लोहे लुह इति गतः स अपि कर्षार्थवाची
dhāturlohe luha iti gataḥ sa api karṣārthavācī
(*RRS*, 5.1)

derived from the root *luha* which means to be extracted. Four *śuddha* or pure *lohas* were named: *suvarṇa*, *rajata*, *tāmra* and *loha* (iron). Low melting-point metals such as *nāga* (lead) and *vaṅga* (tin) were known as *pūtilohas*. *Pittala* (brass), *kāṁsya* (bell-metal) and *vartaloha* (five metal alloy) were known as *miśralohas* or alloys. It is noted that by the time of *RRS*, iron came to be known as *loha* or *lauha*, and brass as *pittala* or *pītala*, derived from *pīta tāla* or yellow metal. Along with bell-metal, brass was known as a *kṛtrima loha* or *miśra loha* (10.66).

Gold was categorised; it could be *prākṛta* (native), *sahaja* (natural), *vahni-sambhūta* (fire-produced), *khani-sambhūta* (from the mines) or *rasendra-vedasanjāta* (transmuted from a base metal). One method of purification was to heat gold leaf with salt and red ochre (5.2).

Silver was described as 'compact, clear, bright, heavy, white on cutting, soft, free from fissures, like *śaṅkha* (conch) in colour' (5.26). Silver melted with lead and borax undergoes purification (5.34). The process is practically that of cupellation. Copper or *tāmra* used to come from Nepal (*nepālaka*) or some other foreign country (*mlecchaka*) (5.44). *Nepālaka* is soft, red and resistant to strong hammering.

Vaṅga or tin was stated to be of two kinds: *khuraka* and *miśraka*. The former is endowed with superior qualities: White, soft, cool (to the touch), readily fusible and bright, and does not clink when bent or struck (5.154). *Miśraka* variety of tin is dirty white and was used after killing as an anthelmintic and a curative

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for urinary disorders (5.155).

Nāga or *sīsa* has been described as

द्रुतद्रावं महाभारं च्छेदे कृष्णसमुज्वलम्
पूतिगन्धं बहिः कृष्णं शुद्धम् सीसम् अतः अन्यथा।
drutadrāvaṃ mahābhāraṃ cchede kṛṣṇasamujvalam
pūtigandhaṃ bahiḥ kṛṣṇaṃ śuddham sīsam ataḥ anyathā ।
(5.171)

Readily fusible, very heavy, presents a black and bright appearance on fracture, is of foetid odour and black exterior'.

Apart from gold and copper, the three other metals which played important roles in the history of the ancient India were mercury, zinc and iron, and we would discuss their references in *RRS* later and separately. Now we would discuss some of the alloys mentioned in *RRS*.

A composition of bronze known as *kāṁsya* or *ghoṣa* was described as

अष्टभागेन ताम्रेण द्विभाग कुटिलेन च
विद्रुतेन भवेत् कांस्यम्।।
aṣṭabhāgena tāmreṇa dvibhāga kuṭilena ca
vidrutena bhavet kāṁsyam ।।

(5.205)

Twenty per cent tin bronze is obtained by melting eight parts of copper with two parts of tin, 'best done at Saurāṣṭra'.

There was a process for recovering copper from *ghoṣa* or bell-metal

स्वल्पतालयुक्तं कांस्यं वंकनालेन ताड़ितम्
मुक्तरंगं हि तत् ताम्रं घोषाकृष्टं उदाहृतम्
svalpatālayuktaṃ kāṁsyaṃ vaṅkanālena tāḍitam
muktaraṅgaṃ hi tat tāmraṃ ghoṣākṛṣṭaṁ udāhṛtam
(8.37)

When molten bell-metal is heated with a little *tāla* or orpiment and blown with a bent tube, it is freed of tin of *raṅga*, and what we get is *ghoṣākṛṣṭa tāmra* (copper extracted from bell metal).

Copper-lead alloy made from *mākṣika* or pyrites was known as *śulvanāga* (8.18-19). Sixteen parts of silver and twelve parts of copper melted together was known as *chandrārka* (8.23).

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Varanāga was probably an iron-antimony alloy:

तीक्ष्णं नीलांजनोपेतं ध्मातं हि बहुशो दृढ़म्।
मृदुकृष्णं द्रुतद्रावं वरनागं तदुच्यते।।
tīkṣṇam nīlāñjanopetaṃ dhmātaṃ hi bahuśo dṛḍham।
mṛdukṛṣṇaṁ drutadrāvaṁ varanāgaṃ taducyate ।।

Varanāga, a low melting alloy was made by melting cast iron or steel with *nīlāñjana* or antimony sulphide. *Varaloha* was obtained by melting copper with cast iron or steel (8.12).

Vartaloha has been described as:

कांस्य अर्क रीति लोह अहिजातं तत् वर्तलोहकम्।
तदेव पंचलोहाख्यं लोहविद्भिः उदाहृतम्।।
kāṁsya arka rīti loha ahijātaṁ tat vartalohakam ।
tadeva pañcalohākhyaṃ lohavidbhiḥ udāhṛtam ।।
(5.212)

An alloy of five metallic systems (*pañcaloha*) of *kāṁsya*, copper (*arka*), brass (*rīti*), iron and lead'.

Fused mass of multi-metallic alloy, if grey or yellow, used to be called *piñjarī* (8.21).

Rasa and *Rasaka* in *RRS*

Mercury was reckoned as a very important metallic element in Indian alchemy and believed to be able to 'transmute' base metals to gold, and to provide an 'elixir of life'. It was known as: *raso rasendraḥ sutaśca pārado miśrakastathā 'rasa, rasendra, suta, pārada* and *miśraka*' (1.68). *Rasa* is that *rasanāt sarvadhātunām rasa iti abhidhīyate* which consumes all metals into liquid' or amalgamates (1.77). *Pārada* 'takes the persons across the oceans of diseases'.

Mercury was obtained by distillation of cinnabar or *hiṅgula/darada* in a *Vidyādhara Yantra* (9.57). The distillate was called *hiṅgulākṛṣṭa rasa* (8.37). Cinnabar was known to occur in two varieties: low quality *śukatuṇḍa* or *carmāra* and good quality *haṁsapāda*, having white lines and looking like coral (3.141-144).

Yaśodhara had quoted Nāgārjuna in his *Rasaprakāśasudhākara*: *pārado rasakaścaiva dehalohakarāvubhau* that both *rasa* or *pārada* (mercury) and *rasaka* (zinc ore/metal) when administered, make the body strong. Both the metals are distillation products, and hence the similarity in the names: *rasa* and *rasaka*.

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RRS stated that *rasaka* or calamine occurred in two forms: *durdura*, full of flakes or laminated, and *kāravellaka*, which is non-laminated (2.149). Other *Rasaśāstra* texts have provided other synonyms for *rasaka* such as *kharpara*, *netrarogāri*(zinc salt might have been used in eye-ointments), *rītikṛt*, *tāmrarañjaka*, etc. *Mṛttikā* type ore is yellow, rich in metal, not losing weight when heated. *Guḍa* and *pāṣāṇa* varieties are of inferior quality.

Calamine was supposed to be purified by roasting and plunging in acidic lemon juice, urine, or sour gruel (2.154-155). Zinc ore of Rajasthan occurs in calcitic and dolomitic gangue. Probably the operation recommended in *RRS* removed carbonates by thermal decomposition and acidic dissolution. Smelting involved reduction-roasting of zinc ore with carbonaceous materials and borax in brinjal-shaped crucible or *vṛntāka mūṣā*:

वृन्ताक आकार मूषायां नालं द्वादशकांगुलम्
धत्तुरपुष्पवत् च उर्ध्वं सुदृढं श्लिष्टपुष्पवत्।
अष्टांगुलं च सच्छिद्रं सा स्यात् वृन्ताक मूषिको
अनया खर्परादीनां मृदुनां सत्वमाहरेत्।।

vṛntāka ākāra mūṣāyāṁ nālaṃ dvādaśakāṅgulam
dhatturapuṣpavat ca urdhvaṃ sudṛḍhaṁ ślisṭapuṣpavat ।
aṣṭāṅgulaṁ ca sacchidraṁ sā syāṭ vṛntāka mūṣiko
anayā kharparādīnāṃ mṛdunāṁ satvamāharet ।।

(*RRS*, 10.22-23)

> *Vṛntāka mūṣā* or brinjal-shaped crucible is attached with a twelve-*aṅgula* long tube over it like an inverted flower of *dhattūra*. A hole is made at the length of eight *aṅgula* in the tube. This crucible is used for the extraction of *satva* (metal zinc) from the soft drugs like *kharpara*, etc.

Several techniques of smelting were discussed. According to the first method, the dried charge was to be heated in the crucible, closed and stacked one over another (*mūṣāṃ mūṣopari nyasya*) and the reduction was supposed to be complete as soon as the blue flame (due to carbon monoxide) turned white (*jvāla bhaved nilā sitā yadi*), when the crucible was to be gripped by a pair of tongs and tilted to pour the molten metal (2.157-161). The second method involved mixing the charge thoroughly with binders and putting this in the crucible as pellets (*gutikākṛti*) (2.163-164). The third method involved disillation of the produced zinc metal in the inverted crucible (*adhomukhaṃ mūṣā*) and collection of the condensed vapour in a vessel filled with water kept in a hermetically sealed container below the crucible (*patitaṃ sthālikā nīre satvam*) (2.165-166). This

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last method was commercially followed in India.

RRS described several varieties of brass or *pittala*:

अथ पित्तलम्
रीतिका काकतुण्डी च द्विविधं पित्तलं भवेत्।
सन्तप्ता कांजिके क्षिप्ता ताम्राभा रीतिका मता।।
एवं या जायते कृष्णा काकतुण्डीति सा मता।।
गुर्वी मृद्वी च पीताभा सारांगी ताड़नक्षमा।
सुस्निग्धा मसृणांगी च रीतिरेतादृशी शुभा।।
पूतिगन्धा तथा लघ्वी रीतिर्नेष्टा रसादिषु।।

atha pittalam

rītikā kākatuṇḍī ca dvividhaṁ pittalaṁ bhavet ।
santaptā kāñjike kṣiptā tāmrābhā rītikā matā ।।
evaṃ yā jāyate kṛṣṇā kākatuṇḍīti sā matā ।।
gurvī mṛdvi ca pītābhā sārāṅgī tāḍanakṣamā ।।
susnigdhā masṛṇāṅgī ca rītiretādṛśī śubhā ।।
pūtigandhā tathā laghvī rītirneṣṭā rasādiṣu ।।

Pittala is of two kinds — *rītikā* and *kākatuṇḍī*. The former on being heated and plunged into sour gruel, turns copper-coloured; the latter one turns black by the above treatment (5.191-193).

A good variety of *rītikā* or *rīti* was stated to be heavy, soft, yellow, resistant to hammering or malleable (*tāḍanakṣamā*), brilliant and smooth. An unsatisfactory variety is pale yellow, hard, rough with spots, not malleable, foul-smelling (high sulphur?) and not suitable for medicinal purposes (5.193-194).

Presumably the 'good variety of *rītikā* or *rīti*' is alpha-brass which is known to withstand a remarkable degree of deformation by cold work without the slightest sign of fracture. The other variety of *rītikā*, which is not malleable, could be either high zinc (more than 30 per cent) beta-brass, having low ductility, or leaded brass.

For making statues, 1-4 per cent lead is added in brass to help in fluidity during casting. But lead is almost insoluble in the liquid and solid brass phases, and thus a little excess of lead appears as black globules and elongated grains; this also causes the turnings to break up into small pieces. *Kākatuṇḍī* was probably leaded brass, the source of lead being the zinc ore itself. The *RRS* mentioned (8.18-19) that lead was often used to make *śulvanāga* or copper-lead alloy.

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Brass used to be killed for medicinal purposes by heating with sulphur, orpiment, etc. (2.167 and 5.201).

Ferrous Materials in *RRS*

The *RRS*, though primarily a medicinal text, provides valuable informations regarding the twelfth-fourteenth centuries AD status of Indian knowledge related to the ferrous materials. Such a detailed coverage (*RRS*, 5.70-5.99) had hardly been presented in any earlier literature.

It was stated that there are three kinds of iron: *muṇḍam* (wrought iron), *tīkṣṇam* (cast or carburised iron or steel) and *kāntam* (the magnetic variety or the variety made from magnetite) (*RRS*, 5.70).

Muṇḍaloha could be *mṛdu* type, which softens quickly, is smooth or glossy and does not break or is without fissure (*abisphoṭam*); it could be of *kuṇṭham* variety which expands with great difficulty on hammering; or it could be *kaḍāram* type which breaks when struck with a hammer and has a black fracture (5.71-72).

There are six varieties of *tīkṣṇam* (5.76). The *khara* variety is hard, breaks on bending, free of *pogaras* (hair follicles or hair-like lines) and on fracture, exhibits mercury-like shining surfaces (5.77). The *sāra* variety, 'obtained from white earth', has *pogaras* and its edges can be destroyed quickly (5.78). The *hṛnnāla* variety is whitish black, has *pogara* and is hard to pierce (5.79). The brittle variety looking like hair follicle is known as *aṅga/vaṅga/pogara/tārāvaṭṭa* (5.80). *Vājīra* looks greyish black, and is full of hard *pogaras*, over-spreaded by dense thin linings (5.81). *Kālāyasa* is bluish black, dense, smooth, bright, and its sharpened edge is not spoiled by hammering (5.82). These *tīkṣṇa* varieties are hundred times better (*śatottaram*) than other non-*tīkṣṇa* varieties (5.83).

The *kāntalohas* could be classified according to colour as *pīta*, *rakta* and *kṛṣṇa* after the trinity gods (5.84-86), or according to their magnetic properties:

भ्रामयेत् लोहजातं यत् तत् कान्तं भ्रामकं मतम्।
चुम्बयेत् चुम्बकं कान्तं कर्षयेत् कर्षकं तथा
साक्षात् यत् द्रावयेत् लोहं तत् कान्तं द्रावकं मतम्।
तत् रोमकान्तं स्पुटितात् ततो रोमोद्गमो भवेत।।

bhrāmayet lohajātaṁ yat tat kāntaṃ bhrāmakaṁ matam ।
cumbayet cumbakaṁ kāntaṁ karṣayet karṣakaṁ tathā
sākṣāt yat drāvayet lohaṁ tat kāntaṁ drāvakaṃ matam ।
tat romakāntaṁ sputitāt tato romodgamo bhavet ।।

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Bhrāmaka type is weakly magnetic, causing movement of ferrous materials; *cumbaka* type 'kisses' or causes adherence; *karṣaka* attracts, and *drāvaka* is strongly magnetic. The fifth variety of *kāntaloha*, giving rise to hair-like structures is called *romaka* (5.90-91).

We conjecture that *kāntaloha* was made by reduction of magnetitic ore

क्षेत्रं खात्वा ग्रहीतव्यं तत् प्रयत्नेन धीमता।
मारुतात् पविक्षिप्तं वर्जयेत् नात्र संशयः।।
kṣetraṁ khātvā grahītavyaṁ tat prayatnena dhīmatā ।
mārutāt pavikṣiptaṁ varjayet nātra saṃśayaḥ ।।

'obtained by carefully digging it out of the mines; that which had remained exposed to the sun and the atmosphere was avoided' (5.94), presumably because the oxidised hematite on the surface mines would have different reducibility properties.

It was known that *kāntaloha* (iron obtained from magnetite) vessel was not wetted by oil

तैलबिन्दुर्न लिप्तम् पाके दुग्धं भवति
शिखराकारकं नैति भूमौ
tailabindurna liptam pāke dugdhaṁ bhavati
śikharākārakam naiti bhūmau

or boiling milk 'which does not overflow but rises high like a peak' (5.95). The surface of *kāntaloha* probably adsorbed odoriferous and organo-leptic compounds, as *gandhaṁ hiṅgum tyajati ca tiktatāṃ nimbakalkaḥ* it was stated that asafoetida gives up its odour, and the bitterness of *nīma* (*Azadirachta indica*) decoction is lost when these materials are kept in a vessel made of *kāntaloha* (5.95). Such accurate observations about the non-wetting by oil or milk, and adsorption properties of the *kāntaloha* surface are indeed very fascinating.

The different varieties of iron were 'killed' for medicinal purpose by roasting in air or with mercury, sulphur or cinnabar (5.96-5.148). It was known that

ये गुणा मारिते मुण्डे ते गुणा मुण्डकिट्टके
तस्मात् सर्वत्र मण्डरं रोगशान्त्यै प्रयोजयेत
ye guṇā mārite muṇḍe te guṇā muṇḍakiṭṭake
tasmāt sarvatra maṇḍaraṁ rogarśāntyai prayojayet

the qualities of 'killed' *muṇḍaloha* (roasted in air) and of the *muṇḍakiṭṭaka/ maṇḍara* or the rust of iron are the same, and therefore the latter was also acceptable for medicinal purposes (5.148). We know from modern science that both are oxides of iron.

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The high reactivity of mercury (an intoxicated elephant) with *kāntaloha* (bent hook to restrain or fix the animal) was poetically described (5.91):

मदोन्मत्तगजः सुतः कान्तम् अंकुशम् उच्यते
madonmattagajaḥ sutaḥ kāntam aṁkuśam ucyate

Some Tentative Interpretations

We may now attempt to provisionally interpret some of the *RRS* terms related to the ferrous materials. Nearly 2500 years before *RRS* was composed, India had made for the first time wrought iron by solid state carbothermic reduction process. The samples naturally contained some inclusions of slag.

Over centuries, it was found that the soft variety of wrought or pure iron could be carburised by contact with hot burning charcoal, and this produced some hardening of the samples at least on the surface. Evidently, austenite, ferrite and pearlite phases were formed in the carburised samples. There was a reference to hot forging in the *Kauṭilīya Arthaśāstra* (7.3.8-9).

तेजो हि संधान कारणम्। नातप्तं लोहं लोहेन संधत्त इति
tejo hi saṁdhān kāraṇam । nātaptaṁ lohaṁ lohena saṁdhatta iti

Third century BC Pandurajar Dhibi samples of sickle were found to contain 0.22 weight p.c. carbon and distinct grains of tempered martensite (De and Chattopadhyaya, 1989) which must have arisen due to intentional quenching, hardening, and conversion from the austenite phase (solid solution of carbon in gamma-iron). Hadfield reported that the second century BC Taxilā samples contained 1.2 to 1.5 per cent carbon.

We do not know when India started producing crucible or 'wootz' iron/steel which contained more than 1.7 per cent carbon. Probabaly this technology also was started before the Christian era, as inferred from the Greek and Roman travellers-cum-writers. Such a high percentage of carbon resulted in the cementite (Fe_3C) phase, which contributed to hardness as well as brittleness. The Wootz swords and implements could however be made ductile by careful forging at a not-too-high temperature of 650°C-850°C, when the coarse cementite grains were compressed and elongated in one direction, surrounded by pearlite and ferrite matrix. Reheating and quenching would result in some martensitic transformation. On selective etching, these 'Damascus steel swords' would show white cementite streaks. The finished product, a high carbon steel with cementite streaks in pearlite-graphite-martensite matrix possessed ideal combination of hardness (even at the edges) and ductility. These steel materials, sword, etc. were described as 'of a dull blue colour, marked with ten millions of meandering

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lines' which were the distinctive 'damask' or surface pattern of seggregated white cementite (Sherby and Wadsworth, 1985).

The Gupta era (fourth and fifth centuries AD) in India witnessed spectacular iron technology in Ujjain, where big iron objects were forged in special furnaces. The fourth century iron pillar, now at Meharauli, Delhi, and the tenth century Dhar pillar (43'8" high, the highest in the world) of king Bhoja are unique examples of hot forging of wrought iron.

Both Subandhu (AD 400) in his work *Vāsavadattā*, and king Bhoja (AD 1000-1055) in his *Yuktikalpataru* referred to iron works, pillars and *lohaśāstra* texts on iron technology. Subandhu specifically mentioned in his work the then knowledge on different kinds of magnets and magnetised iron. We have mentioned in the previous chapter Varāhamihira's detailed description about quenching of steel swords (*Bṛ. Saṁ.*, 50.23-26) which definitely resulted in martensitic transformation and hardening of steel. Uses of water, oil, milk, blood and other quenching media resulted in different rates of cooling and different degrees of martensitisation and hardening.

With the aforesaid brief historical and technical discussion we may now interpret the *RRS* terms provisionally.

Muṇḍaloha was presumably wrought iron obtainied by direct solid state reduction. The name probably originated from *Muṇḍiā*, one of the metalsmith tribes in the district of Bastar, whose ancient iron-making process has been scientifically observed and recorded by Prakash and Igaki (1984). Low carbon materials *mṛdu* was soft; *drutadrāva* is better translated as 'softening quickly' rather than 'melting quickly', since wrought iron would not have a low melting point. With more carbon, *kuṇṭham* and *kaḍāram* varieties became less ductile. *Kaḍāram* was even brittle; black fracture indicated graphite at the interface.

Tīkṣṇam represented in general, carburised iron with appreciable hardness, which could be hypoeutectoid (less than 0.83 per cent carbon) or hypereutectoid (more than 0.83 per cent carbon) steel. *Pogaras* meant hair-like lines which may be surmised as white cementite streaks, coarse enough to be seen by naked eyes (microscope had not been discovered yet). In the *khara* variety, cementite *pogaras* were too fine to be seen, but the brittleness and the 'mercury-like shining fracture surface' were evident. In the *hṛnnāla*, *vājīra* and *kālāyasa* varieties, hot forging and quenching had resulted in hardness as well as ductility. We have explained this point earlier while discussing the medieval practice of damascening of swords. The *hṛnnāla* variety was *chedane atiparuṣam* very hard to pierce. *Vājīra* was described as *pogara vajra samkāśa sūkṣmarekhā* full of hard *pogaras* and overspreaded by dense thin linings. *Kālāyasa* variety

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was described (5.82) as

नीलकृष्ण प्रभ सान्द्रं मसृणं गुरु भास्वरम्।
लोहाघाते अपि अभंगात्मधारं कालायसं मतम्।।
nīlakṛṣṇa prabha sāndraṁ masṛṇaṁ guru bhāsvaram ।
lohāghāte api abhaṅgātmadhāraṁ kālāyasaṃ matam ।।

bluish black, dense, smooth, heavy, bright and its sharpened edge not spoiled by hammering. This description is close enough to that of the damascened steel swords 'of a dull blue colour and with meandering lines'.

The technique of producing 'Damascus steel and sword' from Indian wootz was learnt and perfected by the Arabs in Damascus. Around the time when the *RRS* was written in India, the city of Damascus was conquered by Timur or Tamerlane (AD 1401), and the best metalsmiths were taken to Samarqand. (Pant, 1985) Thus, the Indian technology was gradually taken to the Middle East and Central Asia.

The *kāntaloha*, as we have explained, was the iron made from magnetitic ore, and specially magnetised. Probably it was believed that iron made from magnetite and hematite had different properties. The different types of *kāntaloha* merely referred to the different levels of magnetisation. The classification under headings of *bhrāmaka*, *cumbaka* etc. had existed for at least one millennium before *RRS*. Subandhu (~ AD 400) had mentioned these types in his work *Vāsavadattā*.

Ṛgveda to *Rasaratnasamuccaya* represents a wide time-span of three millennia, during which the Indian literature recorded the progress of knowledge in the areas of minerals, metals and alloys. Archaeological evidences of ancient Indian metallurgy are no doubt more direct and conclusive but are necessarily mute. The underlying philosophy and concepts, evident only in the literary evidences, would be discussed in the next chapter.

Extracts from

Rasaratnasamuccaya

Different methods of making zinc from its ore (*rasaka*)

अथ रसकः—
रसको द्विविधः प्रोक्तो दुर्दुरः कारवेल्लकः।
सदलो दुर्दुरः प्रोक्तो निर्दलः कारवेल्लकः।।149।।
खर्परः परिसन्तप्तः सप्तवारं निमज्जितः।
वीजपूररसस्यान्तर्निर्म्मलत्वं समश्नुते।।

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नृमूत्रे वाश्वमूत्रे वा तक्रे वा काञ्जिकेऽथवा।
प्रताप्य मज्जितं सम्यक् खर्परं परिशुध्यति।।154-155।।
हरिद्रात्रिफलारालसिन्धुभूमैः सटङ्कणैः।
सारुष्करैश्च पादांशैः साम्लैः सम्मर्द्य खर्परम्।।
लिप्तं वृन्ताकमूषायां शोषयित्वा निरुध्य च।
मूषां मूषोपरि न्यस्य खर्परं प्रधमेत्ततः।।
खपरे प्रहते ज्वाला भवेन्नीला सिता यदि।
तदा सन्दंशतो मूषां धृत्वा कृत्वा त्वधोमुखीम्।
शनैरास्फालयेद्भूमौ यथा नालं न भज्यते।।
वङ्गाभं पतितं सत्त्वं समादाय नियोजयेत्।।157-161।।
लाक्षागुड़ासुरीपथ्याहरिद्रासर्ज्जटङ्कणैः।
सम्यक्सञ्चूर्ण्य तत्पक्वं गोदुग्धेन घृतेन च।
वृन्ताकमूषिकामध्ये निरुध्य गुटिकाकृति।
ध्मात्वा ध्मात्वा समाकृष्य ढालयित्वा शिलातले।
सत्त्वं वङ्गाकृति ग्राह्यं रसकस्य मनोहरम्।।163-164।।
यद्वा जलयुतां स्थालीं निखनेत्कोष्ठिकोदरे।
सच्छिद्रं तन्मुखे मल्लं तन्मुखेऽधोमुखं क्षिपेत्।
मूषोपरि शिखित्रांश्च प्रक्षिप्य प्रधमेद्दृढ़म्।
पतितं स्थालिकानीरे सत्त्वमादाय योजयेत्।।165-166।।
तत्सत्त्वं तालकोपेतं प्रक्षिप्य खलु खपरे।
मर्द्ययेल्लोहदण्डेन भस्मीभवति निश्चितम्।।167-168।।

atha rasakaḥ —

rasako dvividhaḥ prokto durduraḥ kārvellakaḥ ।
sadalo durduraḥ prokto nirdalaḥ kāravellakaḥ ।। 149 ।।
kharparaḥ parisantaptaḥ saptavāraṃ nimajjitaḥ ।
vījapūrarasasyāntarnirmmalatvaṃ samaśnute ।।
nṛmūtre vāśvamūtre vā takre vā kāñjike'thavā
pratāpya majjitaṃ samyak kharparaṃ pariśudhyati ।। 154-155 ।।
haridrātriphalārālasindhubhūmaiḥ saṭaṅkaṇaiḥ ।
sāruṣkaraiśca pādāṁśaiḥ sāmlaiḥ sammardya kharparam ।।
liptaṁ vṛntākaṃūṣāyāṁ śoṣayitvā nirudhya ca ।
mūṣāṃ mūṣopari nyasya kharparaṃ pradhamettataḥ ।।
kharpare prahṛte jvālā bhavennīlā sitā yadi ।
tadā sandaṁśato mūṣām dhṛtvā kṛtvā tvadhomukhīm ।
śanairāsphālayedbhūmau yathā nālaṁ na bhajyate ।।

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vaṅgābhaṁ patitaṁ sattvaṁ samādāya niyojayet ।। 157-161 ।।
lākṣāguḍāsurīpathyāharidrāsarjjaṭaṅkaṇaiḥ ।
samyaksañcūrṇya tatpakvaṃ godugdhena ghṛtena ca ।
vṛntākamūṣikāmadhye nirudhya guṭikākṛti ।
dhmātvā dhmātvā samākṛṣya ḍhālayitvā śilātale ।
sattvaṃ vaṅgākṛti grāhyaṃ rasakasya manoharam ।। 163-164 ।।
yadvā jalayutāṁ sthālīṃ nikhanetkoṣṭhikodare ।
sacchidraṃ tanmukhe mallaṁ tanmukhe'dhomukaṁ kṣipet ।
mūṣopari śikhitrāṁśca prakṣipya pradhameddṛḍham ।
patitaṁ sthālikānīre sattvamādāya yojayet ।। 165-166 ।।
tatsattvaṁ tālakopetaṃ prakṣipya khalu kharpare ।
marddyellohadaṇḍena bhasmībhavati niścitam ।। 167-168 ।।

Extracts from
Rasaratnasamuccaya
On Lead and Brass

अथ सीसकम्—
द्रुतद्रावं महाभारं छेदे कृष्णसमुज्जवलम्।
पूतिगन्धं वहिःकृष्णं शुद्धं सीसमतोऽन्यथा।।171।।
पलविंशतिकं नागमधस्तीव्रानलं क्षिपेत्।
द्रुते नागे क्षिपेत् सूतं शुद्धं कर्षमितं शुभम्।।
विघटच्य निक्षिपेत् क्षारमेकैकं हि पलं पलम्।
अर्जुनस्याक्षवृक्षस्य महाराजगिरेरपि।
दाड़िमस्य मयरस्य क्षिप्ता क्षारं पृथक् पृथक्।।
एवं विंशतिरात्राणि पचेत् तीव्रेण वह्निना।
विघट्टयन् दृढ़ं दोर्भ्यां लोहदर्व्या प्रयत्नतः।।
रक्तं तज्जायते भस्मं कपोतच्छायमेव वा।।176-179।।
शिलया रविदुग्धेन नागपत्राणि लेपयेत्।।
मारयेत् पुटयोगेन निरुत्थं जायते तथा।।184-185।।
atha sīsakam —

drutadrāvaṁ mahābhāraṁ chede kṛṣṇasamujjvalam ।
pūtigandhaṁ vahiḥkṛṣṇaṃ śuddhaṁ sīsamato'nyathā ।। 171 ।।
palaviṁśatikaṃ nāgamadhastīvrānalaṃ kṣipet ।
drute nāge kṣipet sūtaṁ śuddham karṣamitaṁ śubham ।।
vighaṭya nikṣipet kṣāramekaikaṁ hi palaṃ palam ।
arjunasyākṣavṛkṣasya mahārājagirerapi ।

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dāḍimasya mayarasya kṣiptā kṣāraṁ pṛthak pṛthak ।
evaṃ viṁśatirātrāṇi pacet tīvreṇa vahninā ।
vighaṭṭayan dṛḍham dorbhyāṁ lohadarvyā prayatnataḥ ।
raktaṁ tajjāyate bhasmam kapotacchāyameva vā ।। 176-179 ।।
śilayā ravidugdhena nāgapatrāṇi lepayet
mārayet puṭayogena niruttham jāyate tathā ।। 184-185 ।।

अथ पित्तलम्—
रीतिका काकतुण्डी च द्विविधं पित्तलं भवेत्।
सन्तप्ता काञ्जिके क्षिप्ता ताम्राभा रीतिका मता।।
एवं या जायते कृष्णा काकतुण्डीति सा मता।।192-193।।
गुर्वी मृद्वी च पीताभा साराङ्गी ताड़नक्षमा।
सुस्निग्धा मसृणाङ्गी च रीतिरेतादृशी शुभा।।195।।
पूतिगन्धा तथा लघ्वी रीतिर्नेष्टा रसादिषु।।196।।
atha pittalam —
rītikā kākatuṇḍī ca dvividhaṁ pittalaṁ bhavet ।
santaptā kāñjike kṣiptā tāmrābhā rītikā matā ।।
evaṁ yā jāyate kṛṣṇā kākatuṇḍīti sā matā ।। 192-193 ।।
gurvī mṛdvī ca pītābhā sārāṅgī tāḍanakṣamā
susnigdhā masṛṇāṅgī ca rītiretādṛśī śubhā ।। 195 ।।
pūtigandhā tathā laghvī rītirneṣṭā rasādiṣu ।। 196 ।।

Extracts from
Rasaratnasamuccaya

On different kinds of Iron (*ayas*) — *muṇḍa*, *tīkṣṇa* and *kānta*

अथायः—
मुण्डं तीक्ष्णं च कान्तं च त्रिप्रकारमयः स्मृतम्।
athāyaḥ
muṇḍaṁ tīkṣṇaṃ ca kāntaṁ ca triprakāramayaḥ smṛtam ।
अथ मुण्डम्—
मृदु कुण्ठं कड़ारं च त्रिविधं मुण्डमुच्यते।।70।।
द्रुतद्रावमविस्फोटं चिक्कणं मृदु तच्छुभम्।
हतं यत्प्रसरेद्दुःखात् तत्कुण्ठं मध्यमं स्मृतम्।।
यद्वतं भज्यते भङ्गे कृष्णं स्यात्तत्कड़ारकम्।।71-72।।
atha muṇḍam —
mṛdu kuṇṭham kaḍāraṁ ca trividhaṁ muṇḍamucyate ।। 70 ।।

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drutadrāvamavisphoṭam cikkaṇaṁ mṛdu tacchubham ।
hataṁ yatprasaredduḥkhāt tatkuṇṭhaṁ madhyamaṃ smṛtam ॥
yadvataṃ bhajyate bhaṅga kṛṣṇaṁ syāttatkaḍārakam ॥ 71-72 ॥

अथ तीक्ष्णम्—
. . . षड्विधं तीक्ष्णमुच्यते।।75।।
परुषं पोगरोन्मुक्तं भङ्गे पारदवच्छवि।
नमने भङ्गुरं यत् तत् खरलोहमुदाहृतम्।।76।।
वेगभङ्गुरधारं यत् सारलोहं तदीरितम्।।78।।
atha tīkṣṇam —
. . . . ṣaḍvidhaṁ tīkṣṇamucyate ॥ 75 ॥
paruṣaṁ pogaronmuktaṁ bhaṅge pāradavacchavi ।
namane bhaṅguraṁ yat tat kharalohamudāhṛtam ॥ 76 ॥
vegabhaṅguradhāraṁ yat sāralohaṃ tadīritam ॥ 78 ।
अथ कान्तम्—
भ्रामकं चुम्बकं चैव कर्षकं द्रावकं तथा।
एवं चतुर्विधं कान्तं रोमकान्तं च पञ्चमम्।।
एकद्वित्रिचतुःपञ्चसर्व्वतोमुखमेव तत्।
पीतं कृष्णं तथा रक्तं त्रिवर्णं स्यात् पृथक् पृथक्।।84-85।।
भ्रामयेल्लोहजातं तु तत् कान्तं भ्रामकं मतम्।।
चुम्बयेच्चुम्बकं कान्तं कर्षयेत् कर्षकं तथा।
साक्षाद्यद्द्रावयेल्लोहं तत् कान्तं द्रावकं भवेत्।।
तद्रोमकान्तं स्फुटिताद्यतो रोमोद्गमो भवेत्।।88-89।।
मदोन्मत्तगजः सूतः कान्तमङ्कुशमुच्यते।।
क्षेत्रं खात्वा ग्रहीतव्यं तत्प्रयत्नेन धीमता।
मारुतातपबिक्षिप्तं वर्जयेन्नात्र संशयः।।92-93।।
पात्रे यस्य प्रसरति जले तैलबिन्दुर्न लिप्तं
गन्धं हिङ्गु त्यजति च तथा तिक्ततां निम्बकल्कः।।
पाके दुग्धं भवति शिखराकारकं नैति भूमिं
कान्तं लोहं तदिदमुदितं लक्षणोक्तं न चान्यत्।।94।।
atha kāntam —
bhrāmakaṁ cumbakaṁ caiva karṣakaṁ drāvakaṁ tathā ।
evaṁ caturvidhaṁ kāntaṁ romakāntaṁ ca pañcamam ॥
ekadvitricatuḥpañcasarvvatomukhameva tat ॥
pītaṁ kṛṣṇaṁ tathā raktaṃ trivarṇaṁ syāt pṛthak pṛthak ॥ 84-85 ॥

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bhrāmayellohajātaṁ tu tat kāntaṃ bhrāmakaṁ matam ||
cumbayeccumbakaṁ kāntaṁ karṣayet karṣakaṁ tathā ||
sākṣādyaddrāvayellohaṁ tat kāntaṃ drāvakaṁ bhavet ||
tadromakāntaṃ sphuṭitādyato romodgamo bhavet || 88-89 ||
madonmattagajaḥ sūtaḥ kāntamaṅkuśamucyate ||
kṣetraṁ khātvā grahītavyaṃ tatprayatnena dhīmatā |
mārutātapabikṣiptaṁ varjayennātra saṁśayaḥ || 92-93 ||
pātre yasya prasarati jale tailabindurna liptaṃ |
gandhaṁ hiṅgu tyajati ca tathā tiktatāṁ nimbakalkaḥ |
pāke dugdhaṁ bhavati śikharākārakaṁ naiti bhumiṁ ||
kāntaṁ lohaṁ tadidamuditaṁ lakṣaṇoktaṁ na cānyat || 94 ||

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10

Resumé

WE have critically surveyed in the previous chapters the references to gems, non-gem minerals and metals in the Sanskrit literatures, from the *Ṛgveda* to the *Rasaratnasamuccaya*, which cover the entire span of three millennia of the ancient India. Since mere recapitulation would be unnecessarily repetitive, we would restrict ourselves in this last chapter, to our observations on the following points:

(a) correlations of the literary evidences with the archaeological data and other historical facts, and
(b) the revelations about the scientific concepts and socio-philosophical attitude in ancient India.

Archaeology and History

Archaeology digs not only the earth but also into the past in a telling manner. In this modern age of sophisticated instrumentation, the ancient artefacts can be accurately analysed and C^{14}-dated through the accompanying organic residues; as a contrast, there are controversies on the dates of several works of literature.

On the other hand, the archaeological samples of minerals and metals are mute, and often do not tell whether these were imported or locally made, and in the latter case, the status of **scientific** knowledge of the indigenous manufacturers. The literary evidences tell us about the state-of-art and the status of concepts and philosophy. Even though the literary evidences on minerals and metals in the Indian scene are scanty, scattered and occasionally of uncertain date, these must be viewed as complementary to the archaeological evidences.

The *Ṛgveda* describes the transition from the neolithic to the chalcolithic period in the Indian history (earlier than second millennium BC), the use of

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conch-shell and conch-pearl, different ill-defined metals, and widespread trade and navigation. Homer referred to the import of tin and ivory from India.

The post-Ṛgvedic literatures describe purification steps, sieving, winnowing, smelting in furnaces using bellows and different kinds of metals — the ornamental and barter metals of gold and silver, low melting point metals lead and tin, copper and the new metal *śyāma* or iron obtained through solid state carbothermic reduction. The art of forging or joining of metals was mentioned.

The problem of correlating archaeological and literary evidences is distinctly severe with the *Ṛgveda* and the epic *Mahābhārata*. The epic was definitely expanded from time to time, and the references to ant-gold, *marakata* or emerald and gem-incrustations must have been later-day insertions. We cannot accept that *marakata* was known to the residents of 1200 BC Hastināpura.

On the other hand, the art of making iron, well-known in 1100 BC Atrañjikherā, was never fully recorded in the literature. High carbon steel was definitely made in the pre-Christian era Taxilā, but the scattered literary evidences came much later. Similarly, zinc and brass were known in Taxilā and during the Kauṭilya's time, and yet the first clear reference to the making of these items came much later from the celebrated Nāgārjuna's pen.

The problem of correlating archaeological and literary evidences is not so great with Pāṇini and Kauṭilya. The writings of Pāṇini and Kauṭilya clearly reflect the contemporary scenes (fifth to third century BC) of material civilization in India. The coins, the multi-bellowed furnaces and beryl mentioned by Pāṇini, and *vṛtta*, the circular discs of carburised iron, *tīkṣṇa*, the steel and *ārakūṭa*, the high-zinc brass of Kauṭilya have all been found in the different pre-Christian era strata of Taxilā.

The Gupta era splendour was fully reflected in the contemporary literatures. The then uses of gems, coins, copper, zinc, brass, iron and steel, the international trade with Sri Lanka and Rome, and the Graeco-Roman influence in India, etc. were revealed in many writings, *Ratnaśāstras, Aṅgavijjā, Amarakośa, Bṛhatsaṁhitā* and so on.

The *Rasaśāstra* texts appeared after the decline of the Gupta era, and portrayed the decadent scenes of the Tāntric period, the continued practices of zinc, brass and ferrous metallurgy, the use of mineral-based medicines and the technological contact with China through Tibet. Ray (1956: 97) believed that the knowledge of zinc metallurgy came to India from China, but this was an erroneous view. India was the first to make zinc and brass; what we learnt from the Chinese were precipitation of copper from solution by scrap iron, the arts of making paper and gunpowder, etc.

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Scientific Concepts Related to Material Science

Notwithstanding the technical excellence related to minerals and metals in ancient India, the question remains as to the level of **scientific** appreciation in the ancient world.

The Harappans were meticulous about measurements and standardisation, and it is a pity that their scripts have not yet been deciphered. The Vedic literatures illustrate basic advancements in linguistics, mathematics, geometry and astronomy which are outside the purview of our studies.

Atharvaveda speculated (4.10.1-7) about the cause of orign of conch-shell and conch-pearl. Along with a mythological theory of these gems originating from 'gods bones', the other theory proclaimed that the materials could have grown in the sea under atmospheric influences. This mixture of belief in mythology and rational thinking continued for centuries. We find Varāhamihira declaring (*Bṛ. Saṁ.*, 80.3) in the fifth century AD that the wonderful variety of gems is caused by the characteristic qualities of the earth, and yet the fourteenth century AD text *Rasaratnasamuccaya* continued to repeat the mythological theory.

Kauṭilya referred to the scientific approach of categorisation of gems according to colour. The *Ratnaśāstra* texts brought in the useful criteria of relative hardness, specific gravity and optical properties towards the identification of gems. The reference to *rasapāka* in Kauṭilya shows that *rasaśāstra* studies had been initiated during his time to transform matter to useful varieties. Alchemy gradually evolved from the sustained efforts of Caraka, Suśruta, Patañjali and Nāgārjuna.

In the meantime, the postulate about the atomic constitution of matter, made by Kaṇāda, was being refined by the followers of the *Vaiśeṣika*, Buddhist and Jain philosophies. Yet there was little correlation between the atomic theories (speculative in nature) and the *rasaśāstra* experiments related to distillation, digestion, reduction, oxidation, sulfidisation, etc. During the Tāntric period we obtain the concept of *sattva/satva* denoting metallic essence, the metal extracted from a mineral or ore. There are references to 'mercury from mercuric sulphide', 'copper from copper sulphate' etc., but no categorical statement to the effect that such an extracted metal is indeed the same as the variety available in native state or obtainable from another source. Iatro-chemistry in ancient India fell short of the European breakthrough in Daltonian Chemistry, and yet by the thirteenth century it had outgrown the earlier alchemical extravaganza.

Scientific Attitude in Ancient India: The Irrational Trends

Chattopadhyaya has articulated in great detail (1976,1977,1982, 1986) what he

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considers to be 'living (scientific) and what is dead (unscientific) in Indian philosophy'. According to him the Indian materialistic philosophy of the *Lokāyata* was systematically denigrated in India by the anti-scientific and Brāhmaṇic philosophy of the *Vedānta*. Prafulla Chandra Ray had earlier (1902, 1909) developed the same theme, and criticised the Brāhmaṇic tradition for introducing the pernicious caste system and the anti-reason theological stranglehold in our sub-continent.

Much of their criticisms are valid. The early casteless Ṛgvedic society gradually introduced a rigid caste system and sanctified it by the so-called 'divine sanction'. The isolation of the low-caste artisans from the high-caste scholars affected Indian science since the early days. We have mentioned in chapter 3 an ancient tradition that the ritual milking pot was **not** to be prepared by a low-caste potter! Even metals like gold, copper and newly discovered iron were considered to possess decreasing social status. The concept of hereditary caste permeated into the subject of classification of minerals. According to *Rasaratnasamuccaya* (*RRS*), diamond could have four colours or 'castes'! What was worse, such a classification theory for materials, based on caste, was claimed to have universal applicability :

पदार्थेषु अखिलेषु अपि
padārtheṣu akhileṣu api
(*RRS*, 4.29-4.31)

We find the excellent compilation *Amarakośa* categorising the materials in four caste-categories, the metallurgical equipments falling under *śūdravarga*. Even the scientifically oriented intellectuals like Caraka, Gotama, Praśastapāda, though not conforming to all the Vedic tenets, tacitly accepted the *varṇāśrama* and the caste-system. The famous Vedāntist Śaṅkara not only supported the caste-injunctions of Manu, but also criticised the atmoic theory of Kaṇāda (*Brahma-Sūtrabhāṣyam*, 2.2.17):

तस्मात् एवम् असारतरतर्कसंदृब्धत्वात् ईश्वरकारणंश्रुतिविरुद्धत्वात्
. . . परमाणुकारणवादे . . . श्रेयोऽर्थिभिरिति वाक्यशेषः
tasmāt evam asāratarkasaṁdrabdhatvāt
īśvarakāraṇaśrutiviruddhatvāt
. . . .paramāṇukāraṇavāde . . . śreyo'rthibhiriti
vākyaśeṣaḥ

Such frontal attacks inhibited free-thinking of scientifically minded but god-fearing intellectuals and diffusion of knowledge across caste barriers.

That the *śūdras* should not be allowed to read the *Vedas* was almost fully

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accepted in ancient India. There was a cult of secrecy, of course nurtured by vested interests. The alchemical and Iatro-chemical research was marked by professional secrecy, and the astounding claims were made :

रसविद्या दृढ़ं गोप्या मातुर्गुह्यमिव ध्रुवम्।
भरेत् वीर्यवती गुप्ता निर्वीर्या च प्रकाशनात्।।
रोगिनां बहुभिर्ज्ञातं भवेत् निर्वीर्यम् औषधम्।
न रोगिविदितं कार्य बहुभिर्विदितं तथा।

rasavidyā dṛḍhaṁ gopyā māturguhyamiva dhruvam ।
bharet vīryavatī guptā nirvīryā ca prakāśanāt ।।
roginām bahubhirjñātaṁ bhavet nirvīryam oṣadham ।।
na rogaviditaṁ kārya bahubhirviditaṃ tathā ।।

(*RRS*, 6.71-72).

That 'scientific knowledge remains powerful when kept secret and becomes useless when made public', and that 'the medicine becomes ineffective when its identity is revealed to the patient'.

The insular attitude in India resulted in over-compartmentalisation of technology. Only specific tribes like *muṇḍas* practised iron-making (hence the name *muṇḍaloha*), *bhīls* practised zinc-making, *turis* gold and diamond-washing, *kāñsārīs* bell-metal trading; there were low-caste gem-engravers and even the *rasaśāstra* experts dealing with plant and mineral-based medicines were known as *vaidyas* or fallen brāhmaṇas. (Roy, 1946) The different castes practising different aspects of trade rarely exchanged informations, only which could result in faster growth of science and technology in India. It has been well said that 'the evils that caste system engendered cannot be over-estimated'.

During Varāhamihira's time there was a healthy respect for foreign scholars (*Bṛ. Saṁ.*, 2.4 and 2.32), but in the eleventh century AD, Al-Beruni observed in India an insular attitude and the vice of vainglory amongst the contemporary Indian scholars. (Sachau, 1910, 1983, Vol.1, pp. 22-23)

At the same time, Al-Beruni noted another reason for the decline of Indian Science: 'Mahmud utterly ruined the prosperity of the country . . . .Hindu sciences have retired far away to other places'. Even earlier, the barbarous invasions of the Huns, Scythians and Saracens had stunned the growth of Indian sciences and arts. Ray (1902, 1909) and Chattopadhyaya (1986) have glossed over this aspect of Indian history.

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A More Sympathetic View

Having noted the casteist and irrational trends in Indian science, we may also record the positive aspects in our tradition.

In the famous *Nāsadīya Sūkta* (*ṚV,* 10.129), the *Ṛgveda* provides the earliest example of India's spirit of enquiry. When the post-Vedic culture degenerated into rituals and regimentation in thoughts, a large number of non-conformist intellectuals such as Kapila, Kaṇāda, Buddha appeared on the scene. They brought back the culture of reason and logic (Pande, 1969), and none of them, except the *Lokāyata* scholars, denied the ethical precepts of the original Āryas.

Pāṇini stressed on proof (*pramāṇa*), original discoveries of knowledge 'which had not existed' (*upajñā*) and their applications (*upakrama*). Kauṭilya stressed on accurate measurements and standardisation in trade and commerce. Whereas the followers of Manu considered philosophy to be a subject subserving the Vedic lores (*Arthaśāstra of Kauṭilya*, 1.2.2-3), Kauṭilya asserted that *ānvīkṣikī* or investigative philosophy was supposed to investigate, by means of reasoning, not only the hazards of economics and politics, but **also** *dharmādharmau trayyām* 'What is spiritual good and evil in the Vedic lore' (*AS*, 1.2.11). It was boldly proclaimed that :

प्रदीपः सर्वविद्यानाम् उपायः सर्वकर्मनाम्।
आश्रयः सर्वधर्मानाम् शश्वत् आन्वीक्षिकी मता।।
pradīpaḥ sarvavidyānām upāyaḥ sarvakarmanām ।
āśrayaḥ sarvadharmānām śaśvat ānvīkṣikī matā ।।
(*AS*, 1. 2.12)

Philosophy is ever thought of as the lamp of all sciences, as the means of all actions (and) as the support of all laws (and duties).

Chattopadhyaya himself has described (1976: 5-7 and 1982: Volume 1, pp. 209-38) how the spirit of debate, enquiry and logic were sustained, during the early Christian era, by Caraka, Gautama and Vātsyāyana, who subscribed to the ethical principles of the *Vedānta* concurrently. Caraka pointed out the merit of scientific debate which 'strengthens conviction by way of removing doubt in the pre-existing stock of knowledge, and breaks the tendency to insularism even of those that would not normally impart their own knowledge to others' (*Caraka Saṁhitā*, 1.25.27, 3.8.15 and 28). In the second century AD, Gotama or Gautama wrote his famous *Nyāyasūtra* (which was the origin of the science of logic in ancient India) and three centuries later, Vātsyāyana wrote the equally famous commentary on it. They emphasized the importances of intellectual doubt (*samasyā*), critical examination of the problem (*parīkṣā*) and final ascertainment (*nirṇaya*) as distinct stages in the scientific and philosophical pursuits.

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Āryabhaṭa (born AD 476) did not subscribe to the traditional notion of five elements. His denial of the fifth element, *ākāśa* or ether, was in accordance with the materialistic philosophy of the *Lokāyata*. (Bongard Levin, 1977) Bhāskara I (AD 629) and later Al-Beruni emphasized on Āryabhaṭa's agnostic approach about the space which is not reached by the solar rays, and the notion 'that which is not reached by perception is not knowable'. Āryabhaṭa's theory of the Earth's rotation around its axis and his scientific explanation for the solar and lunar eclipses invited hostility from those who believed in the earlier cosmogenic doctrines, but there is no evidence that he faced any theological inquisition like Galileo.

Al-Beruni rightly accused Brahmagupta (born AD 598) for indulging in half-truths, for criticising Varāhamihira and Āryabhaṭa (who had demolished the Rāhu theory) and yet 'calculating the diameter of the moon in order to explain her eclipsing the sun'. (Sachau, 1910, 1983, Volume 2, pp. 110-12)

Chattopadhyaya (1976: 256-70) has discussed why the intellectuals of the ancient India, not only Brahmagupta, but also Kaṇāda, Caraka, Gautama, Vātsāyana, Varāhamihira, etc. chose not to go against the Brāhmaṇic or the Vedic concepts and ideals. According to Chattopadhyaya, theirs was an act of 'subterfuge, a technique of evading inquisition'. He further observed that even in the modern world there are scientists who believe in matter as well as the divine (Newton and Einstein believed in God) and that 'they have split personalities'.

A more sympathetic view may be proposed. The issue whether matter has evolved from consciousness (the spiritual view) or consciousness has evolved from matter (the materialistic view) has not yet been finally settled. This could be the famous 'chicken and egg' problem. Most intellectuals of all ages and countries might have preferred not to put all their eggs in one basket (atheistic material science). It is better to remain more open-minded on this issue. (Biswas, 1969 : 19-31 and 99-118)

At any rate, the spectacular scientific achievements in the ancient India clearly show that not everything was dead in the intellectual plane. Whereas Śaṅkara ridiculed Kaṇāda's atomic theory, Śubhagupta commented that if atoms are to be doubted on the ground that these are not demonstratable like macroscopic objects, then one should doubt the human mind also!

Ancient India always believed in accurate observations and experiments. *Atharvaveda* initiated the ancient medical tradition by recommending that the animals in the forest may be closely observed to discover the pharmaceutical properties of the herbs (*AV*, 8.7.23-26). Caraka has laid emphasis on the

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importance and utility of scientific experiments (*Caraka Saṁhitā*, 6.8.132,10.5):

परीक्षायास्तु खलु प्रयोजनम् प्रतिपत्तिज्ञानम्।
सम्यक् परीक्षा हि बुद्धिमताम् कार्यप्रवृत्तिनिवृत्ति
कालौ शंसति। परीक्षाकारिणो हि कुशला भवन्ति।।
parīkṣāyāstu khalu prayojanam pratipattijñānam ।
samyak parīkṣā hi buddhimatām kāryapravṛttinivṛtti
kālau śaṁsati । parīkṣākāriṇo hi kuśalā bhavanti ।।

The entire Āyurvedic science of medicine has been based on experimentation; for example, poisoned food and drinks and antidotes were tried on lower animals followed by trial of drugs on human beings. Abundant material on this topic is available in the *Saṁhitās* of Caraka and Suśruta and in the *Aṣṭāṅgasaṁgraha*. For centuries, this approach was pursued by the *Rasaśāstra* scholars.

The author of the thirteenth-century text *Rasakalpa* wrote:

साक्षात् अनुभवैर्दृष्टो ना श्रुतो गुरुदर्शितः
लोकानाम् उपकाराय एतत् सर्वं निवेदितम्।
sākṣāt anubhavairdṛṣṭau nā śruto gurudarśitaḥ
lokānām upakārāya etat sarvaṁ niveditam ।

I have performed the aforesaid experiments with my own hands and have seen them with my own eyes. They are not recorded from mere hearsay or from the dictation of a teacher. These are being promulgated for the benefit of mankind'. (quoted by Ray, 1956:157 and 370)

Yaśodhara made a similar statment in *Rasa-Prakāśa-Sudhākara*.

The author of the fourteenth century text *Rasendracintāmaṇi* wrote :

That which I have heard of learned men and have read in the *śāstras* but have not been able to verify by experiment, I have discarded. I am committing to writing only those which I have been able to perform with my own hands' (Ray's translation quoted by Chattopadhyaya, 1982, Volume 1, p. 345)

Rasaratnasamuccaya (RRS) of the fourteenth century AD defined who could undertake *rasaśāstra* experiments :

सम्यक् साधन सोद्यमा नानाकर्मपरांमुखा
samyak sādhana sodyamā nānākarmaparāṁmukhā

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> An ideal dedicated student, a hard working, meticulous research worker in *Rasaśāstra*' (*RRS* 6.5-6.7; 6.67-6.68)

and described:

> अल्यन्तोपवने रम्ये . . . तत्र शाला . . .
> सम्यक् वातायनोपेता दिव्यचित्रैः विचित्रिता
> *alyantopavane ramye . . . tatra śālā . . .*
> *samyak vātāyanopetā divyacitraiḥ vicitritā*
>
> The ideal *rasa-śālā* or alchemical laboratory, well-ventilated, well-decorated and set in a pleasing environment' (*RRS*, 6.11-6.58).

The layout and the diversity of equipments were described in detail. (Biswas, 1987: 43-44)

Conclusion

Continuing investigations, both archaeological as well as literary, are likely to augment our knowledge on minerals and metals in ancient India. On the basis of the informations gathered by us so far, we may safely conclude that in the field of material science and technology, ancient India was second to none amongst the contemporary nations in the world.

A variety of reasons, discussed in this chapter, inhibited the rate of scientific progress in this sub-continent, and India failed to match the spectacular intellectual renaissance in Europe. Nevertheless, when the British investigators of the nineteenth century surveyed our sub-continent, they obtained abundant evidences of ancient mines, working metallurgical outfits in the sectors of iron, copper, zinc, brass and gold, well-informed practices related to gems and non-gem minerals and, briefly stated, of the entire gamut of the ancient and medieval Indian traditions in minerals and metals.

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col. Ill. 2.1 *Amethyst*. Manganese containing quartz or *sphaṭika*.

col. Ill. 2.2 Colour in Agate/Carnelian Amongst the earliest gems in India.

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col. Ill. 2.3 *Native Gold on Quartz*. Often ends up in river sand (through metamorphosis) recovered by Indian artisans for ages.

col. Ill. 2.4 *Hope Diamond*, probably part of Great Blue diamond taken from India by Tavernier.

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col. Ill. 2.5 *Hexagonal Ruby* or *Padmarāga.*

col. Ill. 2.6 *The Star of India.*
Largest Sapphire
— 563 Carats.

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col. Ill. 2.7 *Faint green hexagonal beryl* or *vaidūrya. Ratnaśalākā* of Kālidāsa.

col. Ill. 2.8 *Emerald Crystals* in Limestone.

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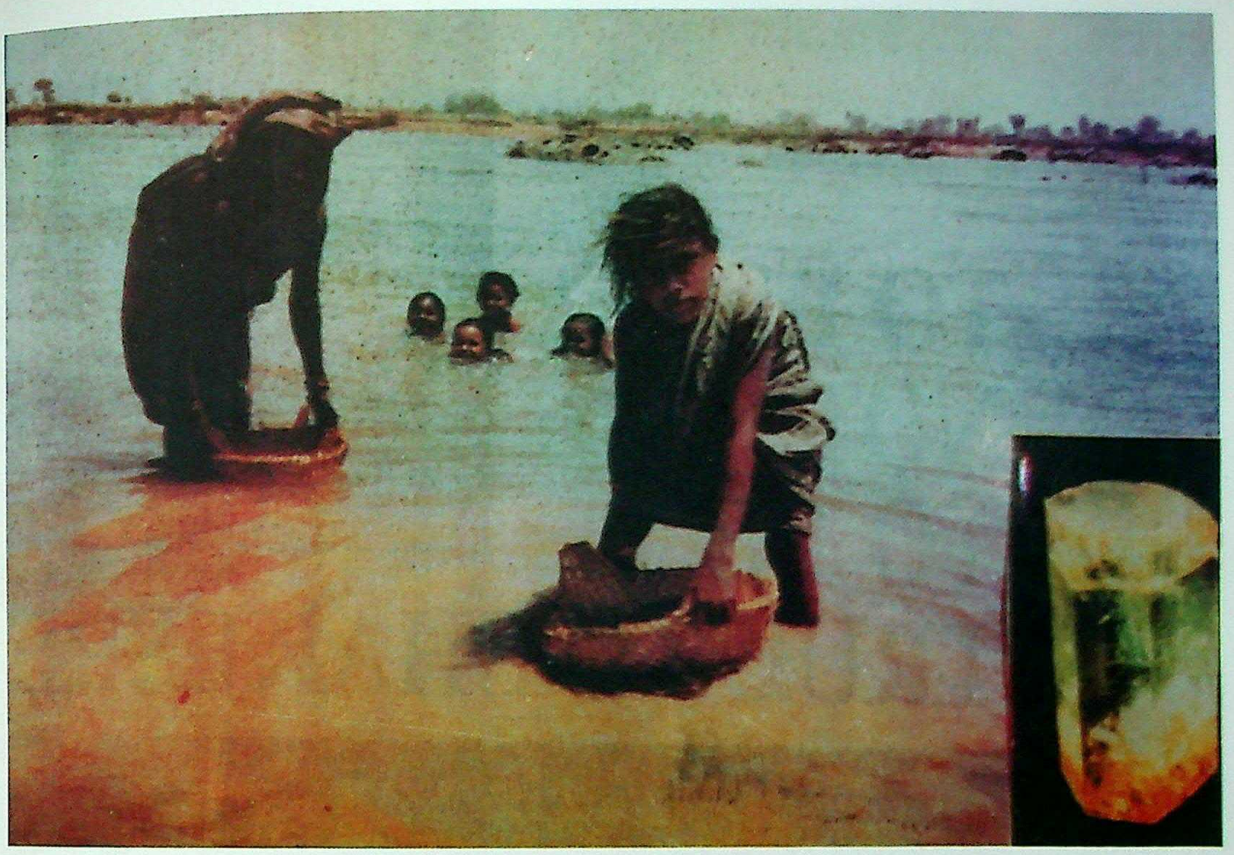
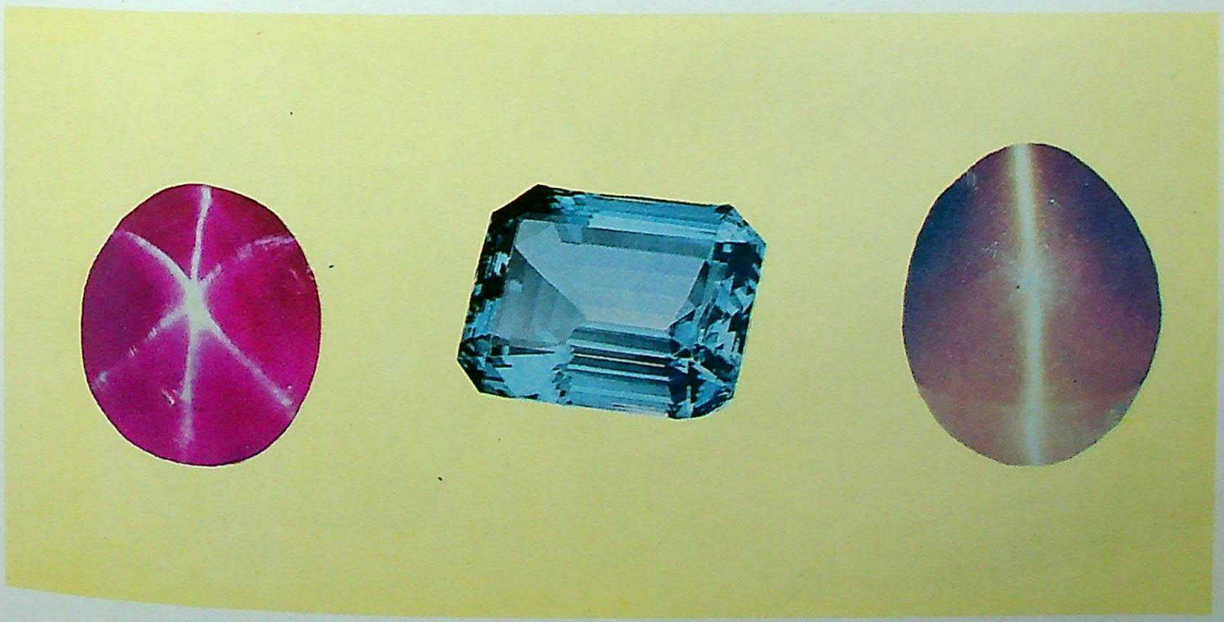


col. Ill. 2.9 *Panning for gems in the Mahānadī.*
Inset an aquamarine or probably green beryl.



col. Ill. 2.10 (a) *Rosser Reeves Ruby* (138.7 carats) from Sri Lankā
— the largest and finest star ruby in the world.
(b) 911 carat aquamarine from Brazil.
(c) The Maharani — 58.2 carat chrysoberyl cat's eye.

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col. Ill. 2.11 *Emerald.* The name was derived from the Sanskrit word *Marakata* meaning the (Egyptian) gem found near desert (*maru*) and sea-coast (*kata*), Masāraka (Egyptian gem) and Smaragdos.

col. Ill. 2.12 *The Taj Mahal Emerald,* Mughal, *circa* 1630-50, Colombian emerald.

col. Ill. 2.13 *Weight for Floor Covering,* Mughal, *circa* 1700, alabaster with gemstone inlay.

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col. Ill. 2.14 *Istanbul Dagger set* with three emeralds, Istanbul Museum.

col. Ill. 2.15 18-19th century 94.5 cm. long sword of the Maharaja of Holkar set with rubies, emeralds, diamond and onyx.

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col. Ill. 2.16 *Skandamātā*. Tanesara — Mahadeva, south of Udaipur. Blue Schist. Rajasthan.

col.Ill. 2.17 *Gaṅgā and Yamunā*. Terracotta. Ahicchatra.

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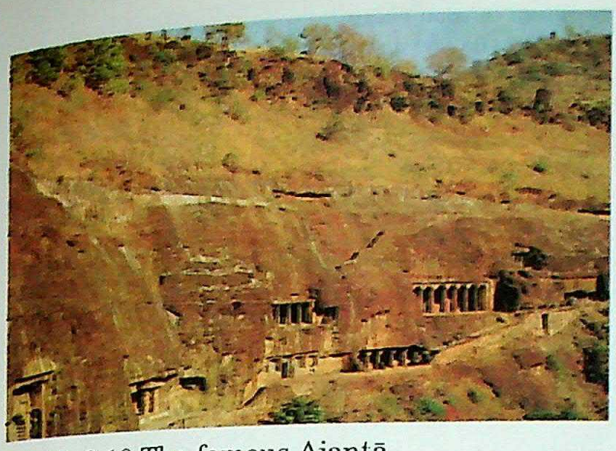
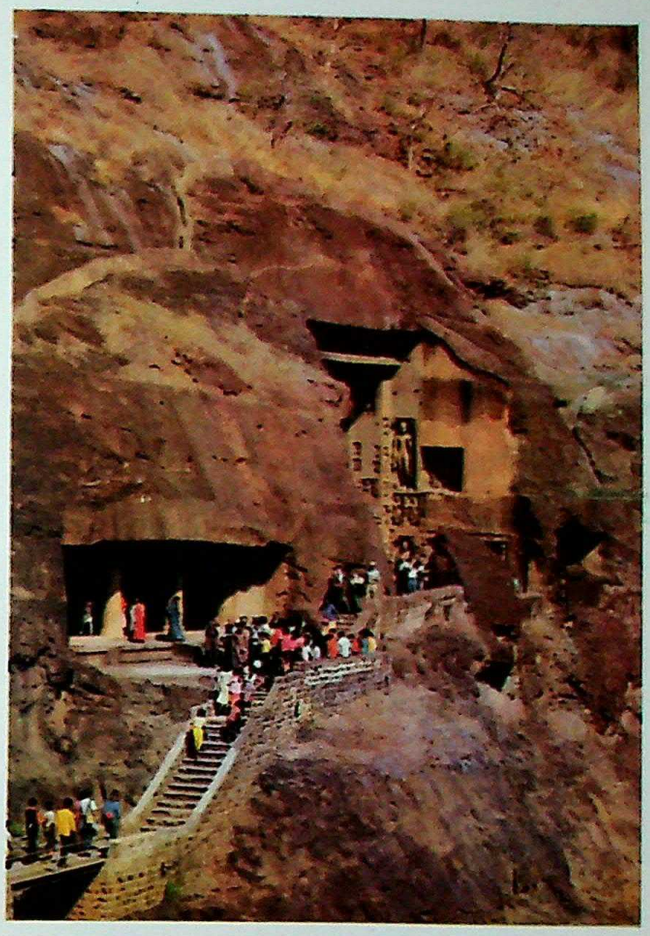
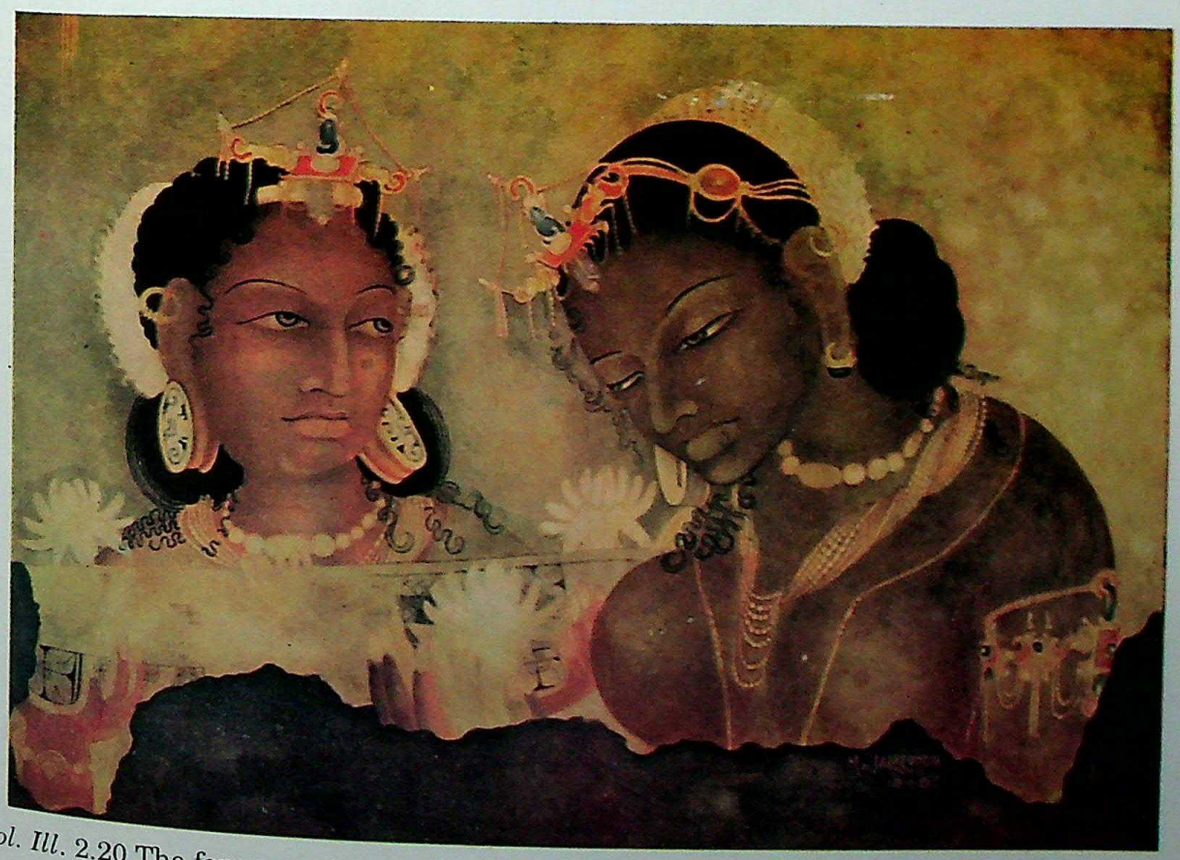


col. Ill. 2.18 The famous Ajantā Buddhistic cave and temple.



col. Ill. 2.19 The famous Ajantā Buddhistic cave and temple have been carved out of basaltic rock.



col. Ill. 2.20 The famous painting (Ajantā, cave no. 1). The pigments used in are lamp black, charcoal, red and yellow ochres, vermillion, ultramarine, terre verte etc.

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col. Ill. 2.21 *Maternity scene* in Black basalt. Could be birth of Kṛṣṇa, Devakī and Kṛṣṇa. Pāla, 11th century AD.

col. Ill. 2.22 *Konārka Temple* 13th century in Khondalite rock.

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col. Ill. 2.23 *Female Musician*. Koṇārka Temple, in Khondalite rock. Erosion is on account of decomposition of the Khondalite mineral.

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col. Ill. 2.24 *Avalokiteśvara* (Bronze). Hemis Gumpha, Leh, 15th century. Inset blue turquoise.

col. Ill. 2.25 *Dancing Tārā*. Gilded Statuette set with turquoise, ruby and other semi-precious stones. 18th Century AD, Nepalese statuette.

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Appendix A

Scientific Information on the Minerals used in the Ancient Period of Human History

Actinolite : Means ray in Greek. Calcium-magnesium-iron amphibole Ca_2 (Mg, Fe)$_5$ (OH)$_2$ (Si_4O_{11})$_2$. Ca-Mg amphibole is *tremolite* (white). Due to iron, actinolite is dark-green. Mixture of the two is *asbestos* (does not contain hardening aluminium). Aluminium makes the structure hard and results in *jade* family of numerals (hardness 6-7). *Nephrite* may be white jade or green due to iron and manganese. The apple-green and emerald green colour of *jadeite* is due to the presence of chromium. It could be mauve or light blue also. The black colour of *chloromelanite* is due to excess concentration of iron in the structure. *Smaragdite* is near actinolite in composition but contains some aluminium. It is thin-foliated and has a light grass-green colour. The word for green is *smaragdus* in Latin and *smaragdos* in Greek.

Adamantine Spar : see Corundum

Adularia : see Feldspar

Agate : see Quartz

Alabaster : see Gypsum

Albite : see Feldspar

Almandine : see Garnet and Ruby

Almandite : see Garnet

Amazon Stone : see Feldspar

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Amber : This is a fossil resin consisting of oxygenated hydrocarbons. C:H:O ratio is approximately 10 : 16 : 1. Part of it yields succinic acid. Colour yellow, sometimes reddish, brownish or whitish. Sometimes fluorescent and luster resinous. Melts at 250-300°C. Of vegetable origin, altered by fossilization, found on the shores cast up by the waves after a heavy storm. Amber was early known to the ancients as *electrum* (electrical susceptibility) whence the word electricity was derived. The word *electrum* was used for gold-silver alloy also.

Amethyst : see Corundum and Quartz

Andradite : see Garnet

Aquamarine : see Beryl

Asbestos : see Actinolite

Aventurine : see Feldspar and Quartz

Balas Ruby : see Ruby

Beryl : $Be_3Al_2(SiO_3)_6$ sometimes a little Na, Li or Cs replacing Be. Hardness 7.5-8.0. Several varieties. *Emerald* bright green contains little chromium. Pure beryl hexagonal prism, pale green.

Aquamarine : is bluish-green. *Heliodor* is golden beryl, yellow due to trace of iron. Beryl is harder than hexagonal apatite and green tourmaline. Differs from Chrysoberyl by its form, see Chrysoberyl which is $BeAl_2O_4$. Beryl can be blue like sapphire (Al_2O_3) just as oriental emerald (Al_2O_3) looks like emerald (beryl) in its green colour.

Bitumen : see Coal

Blood-Stone : see Quartz

Bone Turquoise : see Turquoise

Borax : Composition $Na_2B_4O_7$, $10H_2O$ Hardness 2-2.5 white. Vitreous to resinous luster. Obtained from evaporation of saline lakes and salt deposits in Kashmir and Tibet. Used as flux for soldering, as antiseptic, washing etc. Called *burag* in Arabic which included *niter* sodium carbonate, also *natron* of the Egyptian crude borax known as *tincal* by the Europeans.

Cacholong : see Quartz

Calcite : $CaCO_3$. Hardness 3. Highly birefringent. In crystal form also known as Calc Spar, Iceland Spar, Satin Spar etc. In granular massive to crypto-crystalline kind occurs as rock *limestone, marble* (meta-morphic, higher density) and *chalk*. Various colours due to impurities. *Onyx marble*

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(banded) also known as *oriental alabaster*. Chalk, composed of the shells of minute sea organisms, leaves a trace on a board.

Dolomite is $CaMg(CO_3)_2$ constituent of dolomitic limestone.

Carbuncles : see Garnet

Carnelian : see Quartz

Cassiterite : Main ore of tin. SnO_2. Hardness 6-7. sp. gr. 6.8-7.1 Adamantine luster : Colour brown or black. Occurs in granitic rock or pegmatites. Also alluvial washings. Occurs in Malay Peninsula, coast of Sumatra etc.

Cat's Eye : see Chrysoberyl and Quartz

Ceylonite **:** see Ruby Spinel

Chalcedony : see Quartz

Chalcocite : Cuprous sulphide. Cu_2S

Chalcopyrite : Copper Pyrites. Brass Yellow tarnished. $CuFeS_2$

Chalk : see Calcite

Chloromelanite : see Actinolite

Chrysoberyl : $BeAl_2O_4$. Hardness 8.5. Tabular and not hexagonal crystallization. Ordinarily pale green but trace impurity of iron makes it yellow. *Chryso* means golden. *Cat's eye* has greenish colour and exhibits a fine chatoyant effect. Available in Sri Lanka.

Chrysolite : This is a group of orthosilicate minerals of general formula $R_1^{II}R_2^{II}(SiO_4)$ where R_1 and R_2 are usually combinations of Mg, Fe, Ca, Mn etc.

The *chrysolite* sub-group include *Olivine* and *Peridot* having Mg and Fe in the structure, the Mg/Fe ratio varying from 16 to 2. There is some replacement of Si by Ti. *Olivine* is olive-green, sometimes bottle-green or yellowish green. *Peridot* is clear fine green. *Chrysolite*, named from chryso (gold) is yellow. E.S. Dana commented that "the *chrysolithus* of Pliny was probably our topaz; and his *topaz* our chrysolite".

Chrysoprase : see Quartz

Cinnabar : HgS. Only common mineral of mercury. Bright red to reddish brown in colour and *vermilion* streak. Occurs in slates, shales, sandstones, mixed with clay, bitumen. Major occurrence in Spain, Dutch Guiana, China etc. The name 'cinnabar' is supposed to come from India, where it is applied to the red resin, dragon's blood, zinzifrah in Persian.

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Theophrastus mentioned cinnabar yielding quicksilver (mercury).

Citrine **:** see Quartz

Coal : Plant residue converted into carbonaceous material. Anthracite intermediate product gradually converted to bituminous coal containing hydrocarbon oil or tar yielded during distillation.

Coral : Sub-marine calcareous growth of *Isis Nobilis* insect.

Corundum : Aluminium oxide. Al_2O_3. White if pure. Many varieties of different colours due to traces of specific impurities. *Sapphire* is blue (due to Ti, Fe & Co). True or Oriental *Ruby* is red. Oriental Topaz Yellow. *Oriental Emerald* green *Amethyst* purple. The term *sapphire* is used in general sense for all colours except red. *Asteriated* or *Star Sapphire* shows stallate opalescence or asterism which is due to the presence of minute cylindrical cavities which lie parallel to the prism planes. *Adamantine Spar* from India is dark to translucent corundum, looking greenish or bluish by transmitted light. *Emery* is granular corundum. May be black or grey due to intimate association of magnetite or hematite.

The name originated from the Indian word *kuruvinda* or *karundaka*.

Diamond : Pure carbon C. Hardness 10 in Moh's Scale (highest). Harder and heavier (sp. gr. 3.52) than quartz. Luster adamantine to greasy. Colour white or sometimes yellow, blue due to impurities. High refractive index. Sometimes shows phosphorescence when rubbed. When full of flaws, used chiefly as abrasive. If flawless, used as gem. Weighed in carats (0.2 g).

Diamond works started in Brazil during the early part of the eighteenth century and in South Africa during 1867. Before that India was the chief producer.

The word originated from the greek word *adamas*, alluding to its hardness.

Dolomite : see Calcite

Electrum : see Amber and Gold

Emerald : see Beryl

Emerald Oriental : see Corundum

Emery : see Corundum

Essonite : see Garnet

Feldspar : Group of minerals. Three important sub-classes:

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Orthoclase, α monoclinic; *Microcline*, β triclinic both $KAlSi_3O_8$ where K may be partly replaced by Na; and third *Albite* $NaAlSi_3O_8$ and Plagioclase series, Na partly replaced by Ca in the structure.

Adularia is a low temperature variety of pure orthoclase. Crystallisation at high temperature, above 900°C, produces *Sanidine*.

Beautiful green *Amazonstone* is a variety of microcline, has the usual triclinic twinning striations and grating structure.

Aventurine feldspar is a variety of albite with reddish reflection from certain planes due to thin lamellae of hematite. *Perthite* is a flesh-red aventurine feldspar consisting of inter-laminated orthoclase and albite. *Microcline-perthite* is a similar interlamination of microcline and albite. When the structure is discernible only with the help of the microscope, it is called *microperthite*.

Moonstone, available in Sri Lanka, is a microperthitic to sub-microperthitic intergrowth of orthoclase and albite in an arrangement of thin layers exhibiting a pearly opalescent reflection or schiller or a delicate play of colours. It has beautiful blue bloom and lovely sheen.

Sunstone is a variety of oligoclase, Na-Ca feldspar containing little K and Ba feldspar. A play of colour is a common character, fire-red, yellow, blue, green etc. This is due to interference of light, caused by reflection from thin lamellar inclusions of various minerals such as hematite, goethite etc. Associated with granite and igneous rocks.

Fluorite : Fluorspar. CaF_2 Hardness 4. Octahedral or dodecahedral crystals. Luster vitreous. Colour usually white but varies over a wide range — violet, blue, yellow, red — even in different portions of the same specimen. Modified by heat, pressure, radiation etc. which also cause phosphorescence. High birefringence. Used as flux, in metallurgy, in making opalescent glass, as ornament gems.

Galena : PbS. Luster metallic. Colour and streak grey. Heavy, sp. gr. 7.4-7.6. Hardness 2-2.5. Sometimes contains native silver and gold.

Garnet : Orthosilicate group of Minerals. Latin *granatum* (= pomegranate). $R_3^{II}R_2^{III}(SiO_4)_3$ in which R^{II} could be Ca, Mg, Fe^{II}, Mn^{II} etc. and R^{III} could be Al, Fe^{III}, Cr. Ti etc. Dodeca- and trapezo-hedron crystals.

Grossularite : Essonite or *Hessonite*. *Cinnamon-stone*. These are Calcium-Aluminium garnets with some replacements by Fe^{II}, Fe^{III}, Cr. Variable colour. The name grossularite comes from gooseberry (pale green). *Hessonite* is cinnamon-coloured. Available in Sri Lanka it has a variety

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called *Hyacinth* (inferior) less in hardness than true hyacinth, coloured yellow to yellowish-red. A particular variety of zircon is also called Hyacinth.

Pyrope : means fire-like. It is a magnesium-aluminium garnet with some replacement by Ca, Fe and Cr. Coloured deep-red often transparent.

Almandite : Almandine. The Alabandic *Carbuncles* of Pliny were so-called because these were cut and polished at Alabanda. Hence the modern name almandine or almandite which is an iron (Fe^{II}) — aluminium garnet with some replacement by Mg and Fe^{III}. This is the most common variety usually coloured brownish red and widely found in India and Sri Lanka. *Andradite* is Ca-Al (blackish) garnet.

Grossularite **:** see Garnet

Gold : Au. Yellow. Metallic luster, sp. gr. 19.33 when pure. At present obtained from quartz veins, in the ancient period from alluvial washings.

Electrum is pale yellow to yellowish white. Lower sp.gr. (12.5-15.5) Gold containing 18-36 p.c. silver. The word in Greek means also *amber*.

Graphite : C. Carbon. Very soft. Occurs with nephelite/syenite in India, in pegmatite — veins in Sri Lanka.

Gypsum : $CaSO_4$, $2H_2O$. Greek *gypsos* (= plaster). Hardness 1.5-2.0 Varieties: Crystallized or *Selenite* is colourless or transparent. *Alabaster* is a massive fine-grained variety, white or delicately shaded. *Rock gypsum* may have silica, clay or calcium carbonate as impurities.

Halite : *Rock Salt*. Sodium chloride NaCl. Cubic crystals white. Typical taste. May contain Mg, K Salts. Perfect cubic cleavage. Soft. Hardness 2-3. Formed due to evaporation of sea water. Associated with sedimentary rocks. Enormous deposit in the Salt Range of Punjab, India, at Khewra etc.

Heliodor : see Beryl

Heliotrope : see Quartz

Hematite : Iron sesqui-oxide. Fe_2O_3. Greek *haimatitis* (= blood red). Colour steel grey to reddish brown. It may be specular with metallic luster, compact columnar or red ocherous. The most important iron ore.

Hessonite : see Garnet

Hyacinth : see Garnet and Zircon. Name from purplish blue hyacinth flower.

Iaspis : see Jasper

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Iceland spar : see Calcite

Iolite : Cordierite. $Mg_2Al_4Si_5O_{18}$. Sometimes Mg replaced by Fe^{2+}. Shades of blue. Sri Lanka has a transparent variety in small rolled masses of an intense blue colour, the *saphir d'eau* of jewellers. 'Iolite' stands for violet stone. The name Cordierite is after Cordier, the French geologist.

Jade : see Actinolite

Jadeite : see Actinolite

Jargon : see Zircon

Jasper : see Quartz. The name from Latin *iaspis*, Persian *iashm* and *jashp*.

Kaolin : China-clay. Name from the Chinese hill Kauling. Phyllosilicate. $Al_4Si_4O_{10}(OH)_8$ Dull earthy-white. Soft. Hardness 2-2.5. Product of decomposition of feldspar, granite etc. May be associated with quartz, iron oxide etc. Pure variety for pottery, porcelain or Chinaware etc.

Lapis Lazuli : This richly coloured blue material is a heterogeneous mixture of Sodalite group of minerals:

Lazurite $3Na_2Al_2Si_2O_8$, $2Na_2S$ (Chief constituent)

Haüynite $3Na_2Al_2Si_2O_8$, $2CaSO_4$ and

Sodalite $3Na_2Al_2Si_2O_8$, $2NaCl$

and also several other mineral phases arising out of limestone-granite contact metamorphism.

When powdered, constitutes the durable paint called *ultramarine*.

Massive *lapis lazuli* widely used in the past as gems, for making vases, furnitures, mosaics etc.

The name from Persian *lazhward*, Sanskrit *rājāvarta*.

Lazurite : see Lapis Lazuli

Limestone : see Calcite

Lodestone : see Magnetite

Löllingite : Iron diarsenide. $FeAs_2$. Associated with Fe_3As_4 (leucopyrite), and arsenopyrite FeAsS Luster metallic. Colour silver white to steel grey. Name from Lolling, Austria.

Magnetite : Iron sesquioxide. $Fe^{II}Fe_2^{III}O_4$ or Fe_3O_4 Named after the Greek discoverer Magnes. Strongly magnetic of special variety *Lodestone* possesses polarity and acts like a magnet. Ordinary magnetite is merely

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attracted by a magnet.

Marble : see Calcite

Melantite : Green Vitriol $FeSO_4$, $7H_2O$

Mica : see Muscovite. Name from Latin *micare* (to shine).

Microcline : see Feldspar

Moonstone : see Feldspar

Muscovite : Orthosilicate of Al and K. Sheet structure. Based cleavage. This is common Mica.

Nephrite : see Actinolite

Niter : Sodium nitrate $NaNO_3$. Chilean Saltpetre. Also Potassium nitrate. KNO_3. Forms abundantly in certain soils by the action of bacteria upon animal remains. In great quantities in the desert region of northern Chile. Also in the ancient world, India, Egypt, Persia etc.

Odontolite : see Turquoise

Olivine : see Chrysolite. The name from olive green colour.

Onyx : see Quartz. Greek word means claw, veined gem.

Onyx Marble : see Calcite

Opal : see Quartz, Sanskrit word *upala*, precious stone.

Oriental Alabaster : see Calcite

Oriental Amethyst : see Corundum

Oriental Emerald : see Corundum

Oriental Ruby : see Corundum

Oriental Topaz : see Corundum

Orpiment : Arsenic Trisulphide As_2S_3. Soft. Colour lemon yellow of different shades. Name a corruption of Latin name auripigmentum or golden paint. Also used as a depilatory agent. Associated with *Realgar* which is Arsenic Monosulphide, AsS. *Realgar* is sectile, soft resinous luster. Colour aurora-red or orange-yellow. Found with stibnite, lead, silver and gold. Gives brilliant white light when ignited with saltpetre. Disintegrates on exposure 'Realgar' name from *Rahj al ghār* (Arabic), powder of the mine.

Orthoclase : see Feldspar. Greek for straight and fracture.

Peridot : see Chrysolite

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Perthite : See Feldspar

Piotine : see Talc

Plasma : see Quartz, Greek word for things formed or molded, name used probably because the mineral was used for intaglios.

Pyrite : FeS_2. Pale brass yellow. Metallic luster, splendent to glistening. Hardness 6-6.5. Harder than chalcopyrite. Associated with copper and gold. On the surface altered to a cellular mass of limonite, on iron *gossan* and sulphuric acid, usually by bacterial action. The name pyrite is derived from fire, and alludes to the sparks formed when the mineral is struck with a hammer.

Pyrope : see Garnet

Pyrophyllite : Talc like. Soft. Resembles Steatite or French Chalk. White or yellowish. Peraly luster. $Al_2Si_4O_{10}(OH)_2$. Phyllosilicate.

Quartz : SiO_2. Hardness 7. Many colours due to impurities. Name from Saxon word querkluftertz, meaning cross-veined ore.

A. Phenocrystalline or Vitreous Varieties *Rock Crystal*. Colourless. Star quartz, *Amethyst quartz*, purple or bluish violet due to Mn. Yellow quartz (*false topaz*) or Citrine. *Cat's eye quartz* like chrysoberyl. *Jasper* is impure opaque coloured quartz commonly red or yellow. Aventurine (quartz) is spangled with scales of mica, hematite or other mineral.

B. Cryptocrystalline quartz. Contains variable proportions of water and colloidal silica.

Chalcedony. SiO_2, nH_2O. Wax like luster. Many varieties:

(i) *Carnelian*. *Sard* pale to deep red chalcedony.

(ii) *Chrysoprase*. Apple-green due to nickel content.

(iii) *Plasma*. Bright to emerald green. *Heliotrope* or *Blood-stone* is Plasma with small spots of Jasper (like drops of blood).

(iv) *Agate*. Banded, different coloured chalcedony. Silica deposited in bands — stright or waving.

(v) *Onyx*. Like agate of different colours, but the layers in even planes, and the banding straight, and hence its use for cameos.

(vi) *Sardonyx*. Onyx with layers of sard on carnelian, i.e., red with white or black bands.

Flint and *Chert* are related to chalcedony. *Sandstone* is quartz-

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sand conglomerate rock. *Opal* is amorphous colloidal silica in massive form. Luster vitreous to resinous. Play of colour. Thin curved lamellae of particles in the matrix have differential refractive indices and cause play of colour on rotation. *Cacholong* is opaque, bluish white or porcelain white opal.

Pearl : Nacre consisting of calcium and protein layers around foreign objects inside the oyster, *Pinctada Vulgaris*.

Realgar : see Orpiment

Rock Crystal : see Quartz

Rock Salt : see Halite

Rubicelle : see Ruby

Ruby : See Corundum Al_2O_3; for *true or oriental* Ruby colour red. Latin rubeus (red).

There is another variety of Ruby belonging to a different family: ***Spinel*** Group $R^{II}R^{III}O_4$. *Ruby Spinel* is a magnesia alumina spinel $MgAl_2O_4$. This is clear red on account of some association of chromium in the structure. There may be little iron also. Some varieties are: (a) *Spinel-Ruby*, deep red; (b) *Balas-Ruby*, rose red; (c) *Rubicalle*, yellow or orange red; and (d) *Almandine*, violet, which is different from the almandine in the ***Garnet*** family. *Ceylonite* is Fe-Mg Spinel, opaque, dark green brown or black. Spinel Rubies are distinguished by their octahedral form, hardness and infusibility. Zircon has a higher specific gravity. True or Oriental Ruby is harder and is distinguished optically. Garnet is softer and fusible.

Sal Ammoniac : Ammonium Chloride. NH_4Cl. White incrustation, sublimation product around volcanoes.

Sandstone : see Quartz

Sanidine : see Feldspar

Saponite : see Talc

Sapphire : see Corundum

Sapphire Asteriated/star : see Corundum. Sanskrit equivalent *Sanipruja*?

Sard : see Quartz. Name either from Sardis, capital of ancient Lydias or from Persian word (*sered* = yellow-red).

Sardonyx : see Quartz

Satin Spar : could be ***Calcite*** or ***Gypsum***

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Selenite : see Gypsum. Greek word for moon, alludes to reflection.

Serpentine : Magnesium silicate. Phyllosilicate. $Mg_6Si_4O_{10}(OH)_8$.

Ornamental stone. Leek-green. Smooth, greasy. Massive, lamellar, thin foliated or fibrous like Chrysolite. Also called Chrysotile. Harder than talc. Hardness 3-5. Latin serpens (= snake), in allusion on to the surface pattern of some serpentinite rocks, which resemble the skin of a serpent.

Shell : Conch-shell : The Indian Variety of *śaṅkha*, *Turbinella Pyrum* Linn., and the related genus produce hollow tubular piece, used for bangles, and the inner columella (*kṛśan*) used for making beads.

Silver : Ag. Ductile and malleable metal. Hardness 2-3. Sp. gr. 10-11 pure 10.5. Colour white. Associated with gold and copper in rocks.

Smaragdite : see Actinolite

Soapstone : see Talc

Sodalite : see Lapis Lazuli

Spinel Ruby : see Ruby

Starlite : see Zircon

Steatite : see Talc

Stibnite : Antimony trisulphide. Sb_2S_3. Luster metallic. Highly splendent on cleavage. Colour lead-grey to steel grey, subject to blackish tarnish, sometimes irridescent. Hardness 2. Harder than graphite. Occurs with quartz, galena etc. Chief deposits in Hunan and other areas of central and southern China, Algeria, Mexico etc.

Metastibnite is an amorphous brick-red deposit of Sb_2S_3 occurring with cinnabar and arsenic sulphide.

Sulphur : Element. S. Soft, yellow, resinous luster, typical smell. Formed in volcanic, bacterial activity etc. Associated with gypsum, limestone.

Sunstone : see Feldspar

Sylvite : Potassium Chloride. KCl. Sometimes contains sodium chloride. White, Vitreous luster. Tastes like common salt but bitter.

Talc : Phyllosilicate. $Mg_3Si_4O_{10}(OH)_2$. Faint green, soapy. One of the softest minerals. Hardness 1. Perfect, basal cleavage. Sectile, greasy. Pearly luster Talc could be foliated. The massive variety is called *Steatite* or *Soapstone*. This is coarse granular and greyish green. Yields variable quantity of water on ignition. It occurs in large amount in India and China.

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A related mineral is *Saponite* or *Piotine*. Commonly massive. In nodules, or filling cavities. Soft like fat, hence 'piotine', like soap hence 'saponite'. This is hydrous silicate of magnesium and aluminium, the latter partly replacing Mg and partly Si in the sheet structure. Colour white to dark. Gives out water very readily on heating and then darkens. This is unlike talc.

Tincal : see Borax

Topaz : It has the formula $[Al(F,OH)_2]AlSiO_4$ with variable proportions of F and OH. In an extreme case, it could be $(AlF)_2SiO_4$. Prismatic crystals. Hardness 8. Vitreous luster. Colour is usually straw yellow, wine yellow. Impurities may cause diverse colours such as grey, green, blue, red etc. Often contains inclusions of CO_2. On heating, the mineral may assume a pink or red hue, resembling the Balas ruby. On heating with cobalt solution it becomes blue.

The name *topaz* is from an island in the red sea as stated by Pliny. The *topaz* of Pliny however is not true topaz, since it 'yielded to the file' and therefore not very hard. Pliny and earlier writers included *topaz* under the name *chrysolite*.

Topaz False : see Quartz

Topaz Oriental : see Corundum

Tourmaline : Usually bluish-black, vertically striated prismatic, vitreous to resinous luster. May be of different colours — black, blue, green, red — due to impurities. Birefringent, pyro-electric.

This is a complex sub-silicate of boron and aluminium, with either Mg, Fe or alkali metals (and sometimes fluorine) present. The formula has been variously claimed as $H_9Al_3(B.OH)_2Si_4O_{19}$ or $4R_6Al_2(SiO_4)_3.R_6Al_{12}(B_2O_5)_3$. The composition is still uncertain.

Yellow and brown crystals come from Sri Lanka. The name *turmalin* from *Turamali* in Ceylonese (applied to zircon by jewellers of Sri Lanka) was introduced into Holland in 1703, with a lot of gems from from Sri Lanka.

Tremolite : see Actinolite

Turmali : see Tourmaline

Turquoise : This is a hydrous phosphate of aluminium and copper; may be considered to be an aggregate of orthophosphoric acid molecules hooked with (CuOH) and $Al(OH)_2$ radicals. A typical formula is $H_5(CuOH)$ [Al

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$(OH)_2]_6(PO_4)_4$. Waxy luster. Colour sky blue, bluish green. Has a secondary origin through reaction of copper mineral and feldspar aluminium with apatite or organic phosphorous. Much of the turquoise used in the ancient world was *odontolite* or *bone-turquoise* formed from fossil bone. In the Harappan period, much of turquoise came from Persia, near Nishapur in Khorasan. This was found in narrow seams or in irregular patches in porphyritic trachyte, associated with limonite. A greenish blue variety comes from Siberia. Turquoise is the French word for Turkish. The mineral travelled to the West from Persia through Turkey.

Ultramarine : see Lapis Lazuli

Vermilion : see Cinnabar

Vitriol Blue : $CuSO_4, 5H_2O$. Obtained through bacterial oxidation of chalcopyrite and other copper minerals.

Vitriol Green : Melantite. $FeSO_4,7H_2O$

Zircon **:** This is the orthosilicate of zirconium. $ZrSiO_4$. This may contain some hafnium and little Fe_2O_3, the latter giving it a brownish colour. Pure zircon is colourless, adamantine in luster. But unlike diamond, it is birefringent and less hard (7.5). Its density is 4.68-4.70.

Jargon is a name given to the colourless or smoky zircons of Sri Lanka, in allusion to the fact that while resembling the diamond in luster, they are comparatively worthless; thence came the name *Zircon*. An alternative theory is that the name was derived from *Zarqun* (Arabic) which is from Persian *Zar* (= gold) and *qun* (= colour). *Hyacinth* is the orange, reddish and brownish transparent variety of zircon, used as gem. A particular mineral of the ***Garnet*** family is also called Hyacinth. Zircon, when exposed to hot fumes from a solution of cobalt nitrate and potassium ferro-cyanide gives blue artificial gem *starlite*.

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Appendix B

Words Related to Minerals and Metals in the *Ṛgveda*

Agni : 1.1.1., 3.29.1-2 : Fire which is the cradle of (metallic) gems *ratnadhātamam* (1.1.1), and inherent in the forest (wood) *araṇyornihita* (3.29.2).

Atas : 1.58.2 & 4, 2.4.7., 3.7.3, 4.4.4, 4.7.10, 10.89.5 : Combustible material. Fuel Wood.

Araṇī : 1.127.4, 1.129.5, 3.29.2, 5.9.3, 7.1.1, 10.184.3 : Fire wood from the forest. 'Fire is born from fire-wood'. *siśuṃ yathā navaṃ janiṣṭāraṇī* (5.9.3) fire by friction (3.29.1) *araṇyornihito jātavedā garbha . . . agniḥ* (3.29.2).

Adri : 8.65.8, 9.65.8 : Grinding stone.

Anji : 5.53.4 : Ornament.

Ayas : 1.57.3, 1.163.9, 4.2.17, 6.3.5, 6.47.10, 6.75.12, 10.53.9-10 : Metals in general, probably copper or bronze and not iron in the *Ṛgveda*.

Ayasmaya : 5.30.15 : Metallic (pitcher).

Ayodanṣṭra : 1.88.5, 10.87.2 : Fire, that bites metal.

Āghāti : 10.146.2 : Cymbal (or *Vīṇā* ?)

Āyasī : 1.116.15, 1.118.8, 7.3.7, 7.15.14, 7.95.1: Metallic. *jaṅghā āyasīm* Artificial metallic leg for *viśpalā* (1.116.15, 1.118.8). Also meant hard and resistant to impact, qualifying city; fort etc.

Āhāva : 1.34.8 : Metallic Pitcher. Later Pāṇini defines as cattle-feeding water vessel.

Iṣu : 1.13.4, 1.64.10, 2.24.8, 5.57.2, 8.7.4: Arrow. *ālāktā ayomukham iṣu*

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(6.75.15) Poison and Metal-tipped arrow. (also in Pāṇini 6.2.107).

Ulukhala : 1.28.1-6 : Mortar for grinding.

Ṛṣṭi : 1.37.1, 1.64.4, 1.166.4, 1.169.3, 5.52.6, 5.54.11, 5.57.6, 8.20.11 : Javelin Spear (Thunder) *āsṛukmairā yudhā nara ṛṣvā ṛṣṭīḥ assṛakṣata* : (5.52.6) *ye anñiṣu ye vāśīṣu . . . rukmeṣu khādiṣu* (5.53.4) *aṃśeṣu va ṛṣṭayaḥ patsu khādayo vakṣaḥsu rukmā . . . śiprāḥ śīrṣasu vitatā hiraṇyayīḥ* : (5.54.11) *vāśīmanta ṛṣṭimanto manīṣiṇaḥ sudhanvān iṣumanto niṣaṃgiṇaḥ* (5.57.2).

Kalaśa : 1.117.12 : Pitcher.

Karkari : 2.43.3 : Lute.

Karṇaśovana : 8.78.3 : Ear-ornament.

Karmāra : 10.72.2 : Metalsmith who blows in a furnace and makes metal objects presumably by casting of molten metal.

ब्रह्मणस्पतिरेता सं कर्मार इवाधमत्।
देवानां पूर्व्ये युगे असतः सदजायत।
brahmaṇaspatiretā saṃ karmāra ivādhamat ।
devānāṃ pūrvye yuge asataḥ sadajāyata ।।
(10.72.2)

Kārmāra : 9.112.2 : Metalsmith who makes arrows etc. of metal

जरतीभिः ओषधीभिः पर्णेभिः शकुनानाम्
कार्मारो अश्मभिः द्युभिः हिरण्यवन्तम् इच्छती . . .
jaratībhiḥ oṣadhībhiḥ parṇebhiḥ śakunānām
kārmāro aśmabhiḥ dyubhiḥ hiraṇyavantam icchatī . . . .
(9.112.2)

Kumbha : 1.116.7, 1.117.6 : Pitcher.

Kuliśa : 1.32.5 : Axe (*kuṭhāra*).

Kṛti : 1.168.3 : *haṣteṣu khādiśca kṛtiśca*. A guard and sword. That which cuts. Sword (or Scissor?). In Pāṇini, ***Kṛta*** (7.2.57) means to 'cut into pieces'.

Kṛtnu : 1.92.10 : To cut (wings of a bird). *śaghnīva kṛtnuḥ*.

Kṛśana : 1.35.4, 1.126.4, 7.18.23 : Pearl (the small jewel within the oyster).

अभिवृतं कृशनै . . . हिरण्यशम्यं . . . सविता . . .
abhivṛtaṃ kṛśanai . . . hiraṇyaśamyaṃ . . . savitā . . .
(1.35.4)

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Kṣura : 1.166.10, 8.4.16, 10.28.9 : Razor.

यदा ते वातो अनुवाति शोचिर्वप्तेव श्मश्रु वपसि प्रभूम . . .

yadā te vāto anuvāti śocirvapteva śmaśru vapasi prabhūma . . . (10.142.4)

With wind at its back, fire wipes out the trees and forests and 'shaves' the land just as the barber shaves (with a razor).

Khanitra : 1.179.6 : Spade or digging tool.

khanamānaḥ khanitraiḥ . . . (1.179.6) By the digging spade.

Khanitrima : 7.49.2 : That which is obtained by digging.

sravanti khanitrimā . . . (7.49.2) Flowing canal obtained by digging.

Khādi : Stands for wide-ranging metallic objects such as arm-shield (1.166.9), *hasteṣu khādi* (1.168.3), Wristlet or bangle or armlet *khādi hastaṃ* (5.58.2), anklet *patsu khādayo* (5.54.11), shoulder decoration *aṃseṣu* (*skandhe*) *khādayo* (7.56.13) etc.

Ghan : Hard (Weapon) (1.8.3, 1.33.4).

Tamba : Pitcher. Metallic pitcher *ayastamba* (5.30.15).

Tigna : Sharp. Sharp lance *pavima tignaṃ* (10.180.2).

Dātra : Sickle (for cutting crops such as barley) (8.78.10).

In Pāṇini serrated sickle or crooked knif (3.2.182, 8.4.52)

Dravi : Smelter or metalsmith who melts metal.

तिग्नं . . . परशुः न जिह्वां द्रविर्न द्रावयति दारु धक्षत्

tignaṁ . . . . paraśuḥ na jihvāṁ dravirna drāvayati dāru dhakṣat.

Fire devours wood with its axe-like sharp tongue, just as the smelter melts the metal. (6.3.4).

Draviṇa : The wealth or gem that is obtained by melting e.g. gold and silver (4.5.11, 4.23.4, 4.33.10, 9.109.9, 10.70.7).

Drāvayati : Melts or to melt. See *dravi* (6.3.4).

Dhama : 10.72.2 To blow (in a furnace). See **Karmāra** and **Kārmāra**. Also to purify by blowing (4.2.17).

Dhārā : Sharpened edge of a metallic weapon. *ayaso na dhārām* (6.3.5, 6.47.10).

Dhmātarī : The blower or the metalsmith. *dhmāteva dhamati śiśīte dhmātarī yathā*. As the blower blows to produce sharp flame. (5.9.5)

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Nidhi : 2.24.6, 8.29.6, 10.68.6 : Treasure.

Niṣka : Gold ornamental pieces to decorate neck (2.33.10). May also mean gold coins (1.126.2, 4.37.4, 5.27.2), alludes to goldsmith (8.47.15).

Niṣkagrība : Golden necklace (5.19.3)

Nyochanī : 10.85.6 Ornament?

Pachana : 1.162.6 : Cooking Vessel also *Pachani*, 1.162.13.

Pavi : 10.180.2 : *pavim tignaṃ* Spear sharpened.

Pavitra : 1.28.9, 3.36.7, 8.33.1, 8.101.9 Purifier or Strainer (of Soma).

Paraśu : 1.127.3, 6.3.4, 7.104.21, 10.28.8 : Axe

śiśite paraśuṃ svāyasaṃ Sharpened metallic axe (10.53.9) *prācā gavyantaḥ pṛthuparśavo yayuḥ dāṣā ca vṛtrā hatamāryāni ca . . .*

With big axes came to the east the cow-plunderers — the Dāsas as well as some Āryas . . . . (7.83.1).

Pātra : 1.162.13 : Vessel.

Pāṣya : 1.56.6 : Stone.

Pura Āyasī : 1.58.8, 2.20.8, 4.27.1 : City, Building, Fort, Body-metallic.

Pratyatkān : 5.55.6 : *hiraṇyayān pratytkāṃ* (Golden) armlet (*kavaca*).

Phāla : 4.57.8, 10.117.7 : Plough.

Bāṇa : 6.75.17 : Arrow. *Bunda* in 8.45.4, 8.77.6 and 11.

Bhurija : 4.2.14, 8.4.16, 9.71.5 : Carpenter's tool to make chariot (like *vāsī* ?). May be scissor also.

Maṇi : Gem. That which decorates (*maṇḍana*)

हिरण्येन मणिना श्रुम्भमानाः
hiraṇyena maṇinā śrumbhamānāḥ
(1.33.8)

हिरण्यकर्णं मणिग्रीवम्
hiraṇyakarṇaṃ maṇigrīvam
(1.122.14)

Mantha : 1.28.4 : Grinding or Churning in a mortar.

Yuga : 1.115.2, 1.184.3, 2.39.4, 3.53.17 : Yoke in a chariot, bullock-cart or sacrificial altar etc.

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Rajata : 8.25.22 : Silver.

Ratna : 1.1.1, 1.20.7, 1.35.8, 1.41.6, 1.125.1, 1.140.11, 1.141.10, 2.38.1 Gem. Jewel.

Rayim : 1.73.1, 1.159.5, 2.21.6, 3.1.19, 4.2.7, 4.34.10, 4.36.9, 5.33.6, 6.6.7, 6.31.1: Treasure. From ***Rayim*** the word ***Rajata*** might have been derived.

Rasa : 1.23.23, 1.187.4-5, 5.43.4, 6.44.21 : Liquid essence, extract, juice.

Rāya : 8.4.15-16 : Treasure or wealth as ***Rayim***

Rāska : 8.4.16 : Sharp.

Rādhas : 1.9.5, 1.17.7, 2.13.13, 2.22.3, 4.32.21, 5.13.6, 5.38.1 : Wealth. In 5.52.17 ***Rādhā*** is connected with Yamunā: the wealth of cattle and horses in the valley of the Yamunā : *yamunāyāmadhi śrutamudrādho gavyaṃ mṛje ni rādho aśvaṃ mṛje.*

Rukmā : 1.166.10, 2.34.2 and 8, 5.53.4, 5.54.1, 5.55.1, 5.57.5, 8.46.33, 9.15.5: *vakṣaḥsu rukmā* Chest ornament (made of gold).

Lāṅgala : 4.57.4 : Plough. *śunaṃ kṛṇatu lāṅgalam.* Let the plough cultivate well.

Vajra : 1.32.2, 1.51.7, 6.23.4 : Thunder. Spear. Harpoon to be thrown, or barbed harpoon for fighting.

Vadhara : 1.32.9, 4.22.9, 8.24.27 : Weapon.

Varman : 1.31.15, 1.140.10, 6.75.1, 8.47.8, 10.107.7 : Protective Shield. Breast armour.

Vāśī : 1.37.2, 1.88.3, 8.29.3 : *vāśī āyasī* (8.29.3). Metallic tool-chisel, axe or adze. In the neolithic age this was made of stone. *aśmanmayī vāśī* (10.101.10).

Viśpalā : 1.112.10, 1.116.15, 1.117.11, 1.118.8, 10.39.8 : The lady with metallic leg. *jaṅghāṃ āyasīm viśpalāyai* (1.116.15).

Vṛka : 1.117.21, 8.22.6 : Plough. *yavaṃ vṛkeṇa karṣāthaḥ* (8.22.6).

Vṛṣakhādi : 1.64.10 : Ring.

Veśī : 7.18.17 Needle.

Śara : 1.148.4, 10.87.6, 10.125.6, 10.178.3 : Arrow. Sharpened arrow *śarvā śiśānaḥ* (10.87.6).

Śaru : 1.100.18, 1.172.2, 1.186.9, 4.28.3, 10.87.6, 10.125.6 : Arrow. Elsewhere as in 2.12.10 it means a spear (*Vajra* or *Śūla*).

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Śarya/Śaryā : 1.119.10, 1.148.4, 10.178.3 : Arrow.

Śiprā : 1.101.10, 5.54.11, 8.7.25 : Tiara or Crown (of gold). *śiprāḥ śīrṣasu vitatā hiraṇyayīh* (5.54.11 and 8.7.25).

Śunāsīrā : 4.57.5 and 8 : Plough (***Sīrā***) and its tip (***Phalā***). Also used later in *Śukla Yajurveda,* 12.68. ***Sītā*** means the line or furrow tilled by the plough.

Śūla : 1.162.11 : Metal spike.

Sāyaka : 2.33.10, 10.48.4 : Arrow.

Sīrā : Plough 4.57.5 and 8, 10.101.3-4. Same meaning in Pāṇini (6.2.187).

Sūci : 2.32.4 : Needle for sewing *rākāmahaṃ suḥavāṃ . . . sīvyatvapaḥ sūcyācchidyamānayā dadātu . . .* Let the Goddess Rākā sew with needle our destination (a baby).

Sṛka : 1.32.12, 10.180.2 : Spear or harpoon to be thrown. *Sṛja* means to let go or fly. Sharpened spear *sṛkaṁ saṁśāya* (10.180.2).

Sṛṇī : 10.101.3 : Sickle. *it sṛvyaḥ pakkameyāt* 'Let sickles fall on the ripe harvest'.

Sūna : 1.162.13 : Knife.

Swadhā : 4.10.6 : Ornament.

Swadhiti : 2.39.7, 3.2.10, 3.8.6 and 11, 5.7.8, 7.3.9, 8.102. 19, 10.89.7 : Axe to cut wood and forests (3.8.11). May also mean sword. 2.39.7 contains a statement 'Sharpen the swords/axes on the whetstone:. *kṣṇotreṇeva svadhitim saṃ śiśītam.*

Hiraṇya : 1.22.5, 1.33.8, 1.43.5, 1.122.2, 1.162.16, 2.33.9, 3.34.9, 4.17.11, 9.112.2 : Gold. *hiraṇyasyeva kalaśaṃ* Golden pitcher (1.117.12) *hiraṇyakarṇa* 'One with golden ear ornament or ring' (1.122.14) *ghṛtaṁ na pūtaṁ tanuḥ . . . . śuci hiraṇyam । tatte rukmo na rocata svadhāvaḥ* Fire, Your appearance is like purified *ghī* and pure golden ornaments (4.10.6).

Hiraṇyavartani : 6.61.7, 8.26.18, 10.75.8 : Golden way or river, whose bank-sands contain alluvial gold particles.

Heti : 1.103.3, 1.121.10, 3.30.17, 6.62.9 : Weapon.

Additional Technical Terms in the Other Vedic Literatures
(Not Mentioned in the Ṛgveda)

Aṅgāra : charcoal ; ***Abakṣayanam*** : tongs

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Aṇu : molecule

Añjana : collyrium

Abhra : mica

Ayorasa : metal rust

Aṣṭaprūḍa : coin, a *śatamāna* or eight *śāṇa*

Āma : unbaked pottery

Iṣṭaka : brick

Ukhā : cauldron

Kaṅsa : bronze/bell-metal, Cu alloy with Sn or As etc.

Kārṣṇāyasa : black metal, or iron

Kṛśan : conch-pearl (also in *ṚV*)

Kṛṣṇala : 1/100 of *śatamāna*

Kṛṣṇāyasa : black metal, or iron

Trapu : tin

Trikakuḍa/Traikuta : *Añjana* collyrium from three-peaked Sulaiman mountain

Nistap : heating and melting (of gold etc.)

Nīlalohita : baked (black and red) pottery

Parigha : iron-bar, cudgel

Pariṇaha : iron-chest

Pariśāsa : two-armed iron tongs

Pavamāna : fire, 'that which purifies'

Praśasa : iron axe or chopper

Bhastrā : leather bag or bellow

Bhūtavidyā : physics

Mehaja : silver

Raktikā : 1/100 of *śatamāna*.

Rāśi : mathematics

Lavaṇa : salt, borax

Lākṣā : shellac

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Loha : copper

Lohamaṇi : red gem, copper bead (or ruby?)

Lohita/Lohitāyasa : copper

Śatamāna : gold coin, *pravṛtta* or circular disc

Śaṅkha : conch (also in *ṚV*)

Śalyaka : iron pointed stick

Śāṇa : coin 1/8 of *aṣṭaprūḍa*

Śāsa : sword or knife

Śūrpa : winnow

Śyāma/Śyāmāyasa : dark metal or iron

Samudramaṇi : pearl, sea-gem

Silācī : shellac

Sīsaka/sīsā : lead

Saindhava Lavaṇa : salt from Sindhu or sea

Harita : yellow metal, gold

Hariśiprā : yellow golden tiara

Hiraṇya iṣṭaka : gold-brick

Hiraṇya kaśipu : gold-cushion

Hiraṇya sakala : gold-chips

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Appendix C

Technical Terms Related to Minerals and Metals Mentioned in Pāṇini's *Aṣṭādhyāyī*

Adhikaraṇa : substance, thing, object. (2.2.1, 2.1.49, 2.11, 3.2.124, 3.46, 6.1.34, 8.1.73).

Adhikaraṇa Vicāla : separating or distributing a substance. (5.3.43) *Vicāla* means change in number.

Ayas (Āyas) : probably metal and not merely iron. 5.4.94 states that *anas* (cart), *aśman* (rock), *ayas* (metal), *saras* (river) denote a genus or a name. Examples are Kālāyasam, Lohitāyasam. The former is *ajāti* or genus and the latter a *saṁjñā* or name.

अनस् अश्मन् अयस् सरस् इत्येवमन्तात् तत्पुरुषात्।
टच् प्रत्ययो भवति जातौ संज्ञायां च विषये।।

anas aśman ayas saras ityevamantāt tatpuruṣāt ।
ṭac pratyayo bhavati jatau saṃjñāyāṃ ca viṣaye ।।

Ayas Kaṁsa : metal (iron or bell-metal ?) goblet. (8.3.46)

Ayas Kāma or ***Ayas Kāra*** : black smith. (8.3.46)

Ayas Kumbha : metal pot. (8.3.46)

Ayas Kuśā : metal rope. (8.3.46)

Ayas Pātra : metal vessel. (8.3.46)

Ayasmaya : made of metal, metallic. (1.4.20)

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Words of this type 'are valid forms in the *Chandas* (*Veda*)'

अयस्मय-आदीनि छन्दसि

ayasmaya ādini chandasi

Ayoghana or ***Ayoghaṇa*** : metallic (iron) hammer or forge hammer-whereby the iron is deformed. Here the iron metal is clearly indicated.(3.3.82). The text 3.3.79 — 3.3.83 explains the use of *ghan* equivalent to *han* — destroy or deform. *Udghana* means carpenter's bench. *Vighana* means hammer or mallet. *Drughana* or *Drughaṇa* means an axe (3.3.82). *Stambaghana* means small hoe for weeding clumps of grass. *Parigha* or *Paligha* (3.3.84 and 8.2.22) means 'an iron beam used for locking or shutting the gate, an iron club'.

Ayo-Vikāra : iron work, iron fabric. (4.1.42)

Āyah-Śūlika : iron spike or a daring courageous person. (5.2.76)

Aśman : stone, rock. (4.2.80., 5.4.94, 6.2.9)

Aśmara : pertaining to stone or gravel. (4.2.80)

Aśmārma : stones of a ruin. (6.2.91)

Ākarika : miner, mining officer, mining revenue. (4.3.75). *Ayasthāna* means income of the treasury or *Saulkaśalika* derived from custom house. *Ākarikam* is 'revenue derived from mines'.

Ākarṣa : attraction, touchstone. (4.4.9)

ākarṣa iti suvarṇa parīkṣārtho nikaṣopala ucyate — a touchstone by which gold is tested, a streak plate.

Ākarṣaka : expert in using a touch stone. (5.2.64)

Āsu : to press out (*soma* juice), to distil. (3.1.126)

Āsutivala : who prepares *Soma*, distiller. (5.2.112., 6.3.118)

Iṣṭaka : brick. (6.3.65)

Utkara : anything dug out. (4.2.90)

Utpāva : purifying (*ghī* etc.) using fire. (3.3.49)

Uttama-Naiṣkika : worth the highest *niṣka* (gold coin). (5.1.20)

Uda-Peṣam : grinding in water. (6.3.58)

Upacāyyapṛḍa : gold, associated with *Upacāyya*, a Vedic sacrificial fire. (3.1.123 and 3.1.131). The usage is from the *Chhanda* (*Vedas*).

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Upajñā : invention, discovery. (2.4.21., 6.2.14)

Upajñāta : invented, discovered (for the first time). (4.3.115)

Upajñātopakrama : application (*upakrama*) of the invention (*upajñā*). (2.4.21).

Uraśchada : breast-plate, armour. (6.4.96)

Uṣita : burnt. (8.3.60)

Ūṣa : salt ground, saline soil. (5.2.107)

Ūṣara : impregnated with salt, salty, saline. (5.2.107)

Ūṣman : heat, glow, hot vapour. (3.1.16)

Ūṣmāya : to emit heat or vapour, to steam. (3.1.16) The idea is to *emit* vapour or heat.

Kaṁsa : vessel, goblet or vessel made of metal, *ayaskaṁsa*, also *payaskaṁsa*, drinking vessel made of metal, or for drinking milk. (6.2.122., 8.3.46)

Kaṁsika : relating to or made of bell-metal. (5.1.25)

Kaṁsiya or ***Kāṁsya*** : relating to bell metal, bell-metal (4.3.168). Does it indicate white copper or brass also ? Brass is yellow.

Kajjala : lamp-black used as collyrium. (6.2.91)

Karmakāra : labourer (3.2.22). *Karmāra* (*Ṛgveda*).

Kāṁsya : white copper, bell-metal, brass (?) (4.3.168).

Kārṣāpaṇa : coin or weight. (5.1.29) *Kāra* means tax, toll, royal revenue. (6.3.10)

Kālāyasa : iron, made of iron. *Kālāyasam iti jātih* (5.4.94). *Many* kinds of black metal and *one* kind of red metal (copper) ?

Kuṭṭa : to cut, crush, bruise. (3.2.155)

Kupya : base metal other than gold and silver. (3.1.114)

Kṣara : distillation. (6.3.16)

Kṣaraja : produced by distillation. (6.3.16)

Kṣariti : to flow, glide, distil. (7.2.34) Distillation of mercury and zinc known?

Kṣāma : scorched. (8.2.53)

Kṣāmavat : charred, burnt to coal/ash. (8.2.53)

Khan : to dig, delve. (3.1.111, 3.2.67, 3.2.184, 3.3.125, 4.4.2, 6.4.42 and 43, 6.4.54, 6.4.98, 7.4.62) refers to usage in the *Vedas* of the words compounding *Khan* e.g., *Kupakhāḥ*.

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— digger of well (*kupa* + *khan* + *viṭ*)

"जन-सन-खन-क्रम-गमः; विट् (छन्दसि, उपसर्गे)"

jana-sana-khana-krama-gamaḥ, *viṭ* (*chandasi, upasarge*)

3.2.184 refers to words with affix

Itra after verbs like *khan*; *Sraritram* — a rudder; *Lavitram* — a sickle from; *Lu* (to cut); *Dhavitram* — a fan; *Sabitram* — cause of production; *Khanitram* — a spade; *Caritra* — an instituted observance or character after *Car* or to go. These words imply *Karaṇa* or instrumental *Kāraka*.

श्रर्ति-लू-धू-सू-खन-सह-चरः; इत्रः

śrarti-lū-dhū-sū-khana-saha-caraḥ, *itraḥ*

Ākhanika or *Ākhanikavaka* means spade. *Khanati* means digging. Various declinations of the verb in different tenses e.g., *khanayate*, *khāyate*, *caṅkhanayate*, *cikhaniṣati* etc.

Khanitra or ***Ākhana*** or ***Ākhanika*** or ***Ākhanikavaka*** : spade. (3.2.184 and 3.3.125).

Khanya or ***Khānya*** : coming from excavations or ditches (3.1.123). This and similar words 'were mentioned in the *Chhandas* or the *Vedas*'. The word *Khanija* or mineral not mentioned by Pāṇini, but must have been known.

Kheya : to be dug out, that can be dug out. (3.1.111)

Ghana : compact, solid, hard, firm, dense. (3.3.77-78)

Ghana or Ghṇa : substitute of *Han* — kill. *See* ***Ayoghana*** or ***Ayoghṇa*** etc.

Ghoṣa : noise, tumult, cry. Not yet standing for a metal. (6.3.56)

Cūrṇaya : pulverize, grind, pound, to reduce to powder. (3.1.25). ***Cūrṇa*** etc.

Jambhaka : crushing, devouring using jaws and teeth. (7.1.61) ***Jambhan*** etc.

Jātarūpa : gold (beautiful when it appears) (4.3.153). All words for gold indicating weight or measure end with *aṇ* e.g. *suvarṇa*, *swarṇa*, *hiraṇya* etc.

जातरूपेभ्यः—परिमाणे (अण्)

jātarūpebhyaḥ — parimāṇe (*aṇ*)

Jvala : to burn brightly, blaze, glow, flame (3.1.140., 3.2.150). ***Jvalana*** etc.

Tṛṇah : to crush, bruise. (7.3.92)

Trapu : tin. (4.3.138). Modification (*vikāra*) of Trapu (tin) or made of tin is *Trāpuṣam*. Modification of *Jatu* (lac) is *Jātuṣam*.

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त्रपुजतुशब्दाभ्यामण प्रत्ययो भवति विकारे,
तत् सन्नियोगेन तयोः षुगागमो भवति।
trapujatuśabdābhyāmaṇa pratyayo bhavati vikāre
tat sanniyogena tayoḥ ṣugāgamo bhavati ।

Dātra : sickle, crooked knife, (3.2.182, 8.4.52).

Dṛṣadvat : rocky, stony, (8.2.10). *Dṛṣad* is rock, big which can be seen (*Dṛṣṭa*)

Samidh-Dṛṣada is fire-wood, coal? (5.4.106).

Drava : flowing, fluid. (3.3.27) *Pradrāva* means something flowing away or fugitive. The word derived from *dru*. In the *Ṛgveda* we have *Drāva*, *Drāvin* to mean something which can be melted e.g. gold.

Dravya : substance, object. (4.3.161, 5.3.104)

Dhama or ***Dhmā*** : to blow, blowing (3.1.137 and 7.3.78) *Uddhama* — the act of blowing into (*agnisaṁyogayoḥ*) by fan.

Dhavitra : a fan. (3.2.184).

Dhātu : verbal **base** or root. Not yet **metal** in Pāṇini. Probably the usage had started.

Niṣka : gold coin denoting metallic currency or unit of money. *Dviniṣka*, *Triniṣka*, *Bahunaiṣkikam* etc. (5.1.30). *Uttamanaiṣkika* — worth the highest *niṣka* (5.1.20) . Some form (*rūpa*) of king embossed (*āhatam*) *Rūpyah*. *Dīnāṛah* or *Kedāraḥ* gold coins of Kedāra Kuṣāṇas (5.2.120).

रूपात्, आहत, प्रशंसयोः, यप्
rūpāt, āhata, prasaṃśayoḥ, yap

Origin of *Raupya*? *Māṣa*. also denoted a particular weight of gold.

Ardha or ***Trimāṣya*** etc. (5.1.34).

Niṣka originated probably from *Niṣaya* binding, meaning financial bond.

Niṣ-Kuṣita : extracted, stripped off. (8.3.41)

Niṣ-Koṣana : extraction, husking, shelling, disemboweling, to bring the inner organs out, to eviscerate. Similar to *Niṣkula* — to make the enemy family-less, to remove the seeds of pomegranate.

5.4.62 "*niṣkulāt niṣkoṣaṇe* (*ḍāc*)"

Paṇa : weight of copper used as coin (5.1.34) *paṇah parimāṇe*. See also ***Karṣāpaṇa***.

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Paṇi : *vaṇika* or trader in the *Vedas*.

Paṇya : an article of trade, worth so many *paṇas*. (3.1.101) etc.

Padārtha : thing, material, object. (1.4.96)

Pari-Pavana : cleaning or winnowing corn (8.4.34). *Pu* means to purify *Pāvaka* the purifier. *Pavana* — air. Thus, *Pari-Pavana* means purification by pneumatic jigging, through descent aganist (*pari*) drag in wind (*pavana*).

Pari-Mṛja : wash, cleanse. (3.2.5) *Parimārjanā*.

Pari-Vāpaṇa : to shave (5.4.67). *Kṣura* in *ṚV*.

Pareṅkhaṇa or ***Parengaṇa*** : separating, shaking away. (8.4.32)

Parśu : curved knife, sickle or axe. (5.3.117)

Pāka : baking, cooking, roasting. (4.1.64, 5.2.24)

Pātra : drinking vessel, goblet, bowl, cup, dish. (8.3.46, 5.2.7., 5.4.46 and 53)

Pārāyaṇa : going over, studying. (5.1.72)

Pārā : mercury. The word does not appear in Pāṇini. *Pārā* means going over or distillation?

Pāva : purifying, clarifying, cleansing. (3.3.49, 3.3.28). *Utpāva* distillation, evaporation? *Nispāva* is winnowing or purification through downward movement.

Piṣṭa : crushed, bruised, ground. (4.3.146)

Piṣṭaka : cake, made of flour or agglomerate of fine particles. (4.3.147)

Pūta : cleansed, purified, pure, clear. (6.2.187) This is from *Pu* or to purify.

Pūti : putrid, foul-smelling, stinking, fetid. (5.4.135) *Pūti + Gandha = Pūtigandhi* The rule is given in 5.4.135:

> उत् पूति, सु सुरभि इति एतेभ्य: परस्य गन्धशब्दस्य
> इकारदेशो भवति समासान्ता बहुव्रिहौ समासे
> *ut pūti, su surabhi iti etebhyaḥ parasya gandhaśabdasya*
> *ikāradeśobhavati samāsāntā bahuvrihau samase*
>
> Copper and other sulphide minerals were purified (*Pūta*) in the furnace which produced foul (*Pūti*) smell (*Gahdha*) of sulphur dioxide. Thus furnace is *Pūtigandhi*.

Peṣam : pounding, grinding. (3.4.35 and 38, 6.3.58). *Piṣ* means to grind. Grinding dry (*śuṣka* — or *Rūkṣa*). Grinding to Powder (*Cūrṇa*). These are accusative cases. The instrumental case corresponds to grinding by means of liquid

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(*Snehana*) e.g. *Udpeṣam* means grinding with water. *Tailapeṣam* grinding with oil.

शुष्क-चूर्ण-रूक्षेषु, पिष; (कर्मणिणमुल्)
(3.4.35)

śuṣka-cūrṇa-rūkṣeṣu, piṣaḥ, (karmaṇiṇamul)

स्नेहनवाचिनि करण उपपदे पिषेर्द्धातोः णमुल् प्रत्ययो भवति।
(3.4.38)

snehanavācini karaṇa upapade piṣerddhātoḥ ṇamul pratyayo bhavati.

Prati-Śina or ***Prati-Śīnavat*** : melted, fluid, dropping. (6.1.25)

Prati-Snāta : bathed, washed. (8.3.90)

Prapavana : purifying or straining (*Soma* juice) or filtering. (8.4.34) Derived from the verb *pu*.

Pramāṇa : measure, scale, quantity, standard, authority. (3.4.51, 4.1.24, 5.2.37, 6.2.4 and 12) The idea of 'proof' originated from the sense of referring a standard or previously accepted yardstick.

Pramāthin or ***Pramatha*** : to churn or stir up violently. (3.2.145)

Pralaya : melting, dissolution, annihilation, death. (7.3.2)

Prāleya : produced by melting. (7.3.2) *Prāleyam Udakam*, i.e., melting to a liquid.

Phulla : split or cleft open, expanded, blown (as flower). (8.2.55)

Phena : foam, froth, scum. *Phenala*, *Phenila*, *Phenavat*. (5.2.97 and 99)

Bista : a particular weight of gold (= 80 *ratikās*). (4.1.22., 5.1.31)

Bhaṅgura : fragile, perishable, breakable. (3.2.161)

Bhastrā : a leather bag or vessel, skin, pouch. *Bhastrikaḥ* or *Bhastrikā* means something or somebody transporting by means of a leather bag. *Bhastrayā Harati*. Leather bellows by which iron is heated or grain is carried. *Bhara* = carry, bear.

भस्त्र इति एवम् आदिभ्यः तृतिया समर्थेभ्यः
हरतीत्येतस्मिन्नर्थे ष्ठन्प्रत्ययो भवति।
(4.4.16)

bhastra iti evam ādibhyaḥ tṛtiyāsamarthebhyaḥ
haratītyetasminnarthe ṣṭhanpratyayo bhavati।

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Śvan + Bhastrā = Śvābhastri

"ज्व, आदेः इञि" (7.3.8)

jva, ādeḥ iñi

Śvābhastri means something made of dog leather.

Bahubhastrika means a furnace with many leather bellows (?) (7.3.47)

Bhāṇḍa : vessel, pot, dish, vat etc. (3.1.20)

Bhās : lustre, brightness. (3.2.21, 3.2.177)

Bhāsa : to shine. (3.2.161, 7.4.3)

Bhāsana, ***Bhāsura***, ***Bhāskara***, ***Bhāsvat***, ***Bhāsvara*** : shining, brilliant, luminous, radiant, bright, glittering. (1.3.47, 3.2.161, 3.2.21, 3.2.175, 8.2.9)

Bhida : to split, cleave, break. (3.2.61)

Bhid or ***Bhidura*** : breaking, splitting, piercing, destroying (wood etc.). (3.2.61 and 162)

Bhinna : split, broken. (8.2.42 and 59)

Bhuvar or ***Bhuvas*** : air, atmosphere, one of the three *mahāvyāhṛtis*, *bhu*, *bhuvas* (in the *Vedas*) or *Bhuvar*, and *Swar* or *Swaḥ* (heaven).

भुवस् इत्येतस्य महाव्याहृतेः छन्दसि विषये उभयथा भवति।

8.2.71 : *bhuvas ityetasya mahāvyāhṛteḥ chandasi viṣaye ubhayathā bhavati* ।

Bhū : becoming, being, the world, universe, earth. (3.2.179, 6.2.19)

Bhūmi : the earth, soil, ground, territory. (8.3.97)

Bhettṛ or ***Bhedana*** : breaking, cleaving, splitting. (7.3.86)

Bhrajj, Bhṛjjati, Bhrasj, Bhraṣṭavya : to fry, parch, roast, fried, roasted etc. (6.1.16, 6.4.47, 8.2.36)

Bhraṣṭavya : to be parched or roasted. (6.4.47 and 8.2.36)

Bhraṣṭṛ : one who roasts or parches. (6.4.47 and 8.2.36) Does it also mean the furnace-man? The word is so close to *Bhaṣtrika*. *Bhrāṣṭra* is grid iron or frying pan. (8.4.50)

Bhraj : light, lustre, splendour. (3.2.177, 8.2.36)

Bhraja : to shine, glitter, sparkle. (3.2.177)

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Bhrāsa : (7.4.3, 8.2.36)

Majjana : cleansing. (7.1.60)

Maṇi : a jewel, gem, pearl, precious stone (that which decorates, adorns, embellishes or *Maṇḍa* ?) (5.4.30). See ***Lohitaka***

Maṇi-Prastāra : Scattering or vein of gems. (3.3.32)

Maṇḍa or ***Maṇḍana*** : to decorate, adorn. (3.2.151)

Maṇḍala : circular, round, disc.

Maṇḍūka : a *ṛṣi*.

Matha or ***Mantha*** : to stir, churn. (3.2.145, 5.1.110, 6.3.60)

Māṣa or ***Māṣya*** : a particular weight of gold. See ***Niṣka*** (5.1.34)

Mur : becoming solid, thickening, congealing (6.4.21). *Mūrta, Mūrti* congealed to solidity and shape. *bhakti hime mūrti sākāra rūpa* — Ramakrishna. See ***Mūrti*** later.

Muṣa : to steal, rob, plunder. (1.2.8) *Asmoṣī*, a thief. *Mūṣikakā*, a little rat or mouse, (7.3.46) *Muṣka*, testicle, scrotum.

Mūṣā : crucible does **not** appear in Pāṇini. Probabaly the word came from *Mūṣika* or rat.

Mūrchi : to became solid, thicken, congeal. (8.2.78)

Mūrta : as above. (8.2.57)

Mūrti : any solid body or material form. (3.3.77) It means hardness, solidity, loss of fluidity (ghan), as in the case of curd, solidified metal etc.

3.3.77 : *mūrttau ghanaḥ, (hanaḥ, ap)*

Abhra-Ghana means cloud. *Dadhi-Ghana* (6.1.24) explains *Drava-Murti*, i.e., hardening or coagulation of a fluid as in butter, grease, molten metal etc. as understood by coldness through touch or coagulation. (*śīna*)

द्रवमूर्त्तौ द्रवकाठिन्ये स्पर्शे वर्तमानस्यश्रयेङ्गतौ
इत्यस्य धातोः निष्ठायां परतः संप्रसारणं भवति। (शीन)
dravamūrttau dravakāṭhinye sparśe vartamānasyaśryeṅgatau ityasya dhātoḥ niṣṭhāyāṃ parataḥ saṃprasāraṇam bhavati (*śīna*)
śīnam ghṛtam, śīnā vasā (means coagulation) *śita* refers to coldness.

Mṛja : to wipe, rub, clean, polish, cleanse, purify. (8.2.36) *Kaṁsa-Parimṛt* means cleaning of metallic vessel or bell metal surface. (8.2.36)

Mṛta : dead, deceased. (6.2.116)

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Mṛd : earth, soil, clay, loam, mud. (5.4.39) That which can be squeezed, pounded etc.

Mṛttikā : earth, clay, loam. (5.4.39) explains how the word has come from *Mṛd* with optional affix *Tikan*

मृत् शब्दात् स्वार्थे तिकन् प्रत्ययो भवति
mṛt śabdāt svārthe tikan pratyayo bhavati

Mṛtsā and ***Mṛtsnā*** : good earth or clay or excellent soil (5.4.40) explains that the word is based upon Mṛd and the idea of excellence.

प्रशंसोपाधिकेर्थे वर्तमानान् मृत्शब्दात् सस्न इत्येतौ प्रत्ययौ भवत्:
praśaṃsopādhikerthe vartamānān mṛtśabdāt sasna ityetau pratyayau bhavataḥ

Mṛda : to press, squeeze, crush, pound, smash. (1.2.7)

Mṛdu : very soft, tender. (8.1.12)

Rajata : silver.

Rājata : made of silver, silvery (4.3.154) explains how the affix *aṇ* comes in the sense of its product or its part. *Rajata-Rājata* ; *Sīsa-Saisam* (lead); *Loha-Lauham* (iron) etc. *prāṇi-rajatādibhyaḥ-añ*

Rūkṣa : rough, dry, arid.

Rūkṣa-Peṣam : dry grinding. (3.4.35)

Rocanā : a particular yellow pigment.

Raucanikā : yellowish, coloured with yellow pigment (4.2.2) deals with other colouring agents e.g. *Lākṣā* (lac) *Lākṣikam*; *Śakala*, *Kardama*, *Haridrā* *Hāridram*. These are mostly organic natural dyes.

Lava and Lavana : cutting, cutting off. (3.3.28)

Lavaka : cutter.

Lavaṇa : salt, saline, briny. (3.1.21, 4.4.24)

Lāvaṇika : a salt vendor. (4.4.52)

Lavaṇīya : to function like salt. (7.1.51)

Lavaṇasya : to desire salt. (7.1.51)

Lavitra : a sickle, reaping hook. (3.2.184)

Lākṣā : lac, red dye. (4.2.2)

Lū : to cut, sever, divide.

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Lohitaka : of red colour, reddish. *Lohita* (red) plus affix *Kan* becomes *Lohitaka* in the sense it is *Maṇi* (gem). *Lohitaka* is ruby. (5.4.30) says "*lohitāt, maṇau kan*" *Lohitikā* means reddened with dye (*Lākṣā*).

Lohitāyasa : red metal, copper, made of it. (5.4.94). See note on ***Ayas***.

Lauha : iron. Does **not** appear in Pāṇini. Probably known as *Kālāyasa*, and **later** *Lauha* from *Lu* or *Lava* to cut, **not** from *Lohita*.

Varṇa : colour, tint. (4.1.42, 6.2.3)

Varman : defensive armour. (3.1.25, 6.4.170)

Vārka-Rūpya : stamped with *Vṛka* die. (4.2.106)

Vikaṣa : to shine, be radiant. (3.2.143)

Vikira : scatter.

Vighana : hurt, mallet, hammer. (3.3.82) See ***Ayoghana***

Vinīya : sediment, sin. (3.1.117)

Viparśu : separated from the side. (6.2.177). See *Parśu* (5.3.117)

Vipātana : melting, liquefying (7.3.39) refers to melting of fat. *Sneha Vipātana.*

Mahābhāṣya adds *Loham Vilāpayati* — copper melts ?

Vibhakta : isolation, separation, seclusion. (2.3.42)

Vibhāga : partition, division, allotment, share (3.3.137). *Kāla Vibhāga.*

Viśīrṇa : broken, shattered, scattered, dispersed from the word *śṛ*. (8.2.42 and 77)

Vista : a particular weight of gold. (4.1.22) Also *Bista* — a weight of gold equal to 80 *Raktikas*.

Thus *Dvi-Vista*, *Tri-Bista* etc.

Vaidūrya : a cat's eye gem (4.3.84) says that this is obtained from *Vidura* plus affix *ya* in the sense 'what manifests itself there'. In the *Bhāṣya* it is added that the gem was actually found in the mountain of *Vālavāya*. The rough stone used to be worked upon in the city of *Vidura*. Pāṇini had made the two names synonymous. Anyway the city was evidently the source of polished gem of *Vaidūrya*.

"विदुरात्-ञ्यः।।"

वृत्तिः।। विदूरशब्दात् ञ्यः प्रत्ययो भवति ततः

प्रभवति इति एतस्मिन् विषये।।

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"vidūrat-ñyaḥ ।
vṛttiḥ ।। vidūraśabdāt ñyaḥ pratyayo bhavati tataḥ
prabhavati iti etasmin viṣaye ।।

कारिका: वालवायो विदूरं च प्रकृत्यन्तरमेव वा।
न वै तत्रेति चेद् ब्रूयात् जित्वरीवदुपाचरेत् ।।

kārikā : vālavāyo vidūraṃ ca prakṛtyantarameva vā ।
na vai tatreti ced brūyāt jitvarīvadupācaret ।

Varanasi used to be known by the merchants as Jitvari.

Vy-Ut-Kramaṇa : going apart, separation. (8.1.15)

Śaṅku : a peg, nail, spike. (8.3.97)

Saṅkuṣṭha (fixed) on the nail.

Śarkarā : gravel, grit, shingle, sugar. *Śārkara*, *Śarkarika*, *Śarkarila*, *Śarkariya*, *Śarkarāvan* etc. means sugary or gravelly, gritty, stony. (4.2.80 and 93, 5.2.104 and 105).

Sikatā means sand; *Saikata* sandy

Śalātura : birth place of Pāṇini, the abode of his ancestors. Modern Lahur, which is 4 miles from Ohind on the right bank of the Indus. (4.3.94)

Śākala : dyed with *Śakala* (organic?). See ***Raucanikā***

Śārada : autumnal. fresh, new. (6.2.9) *Śārade Anārtave* may not mean *Ṛtu* or autumn. Then it means fresh, new.

Śilā : stone, rock. (5.3.102) *Takṣa* (wood-cutter, carpenter) *Śilā* — famous city. (4.3.93) *Śileya* means stony, rocky. (5.3.102)

Śīna : congealed, frozen, **coagulated**. See ***Mūrti*** for distinction between *Śīna* (coagulated) and *Śīta* (frozen cold). (6.1.24-26)

Śuci : clear, clean, pure. (7.3.30)

Śuddha : clear, clean, bright. (5.4.145)

Śubhra : radiant, shining. (4.1.123, 5.4.145)

Śulka-Śāla : custom house. (4.3.75)

Śuṣka-peṣam : dry grinding. See ***Peṣam***

Śūrpa : a winnowing basket. (5.1.26)

Śaurpa : related to, measures, by ***Śurpa***

Śula : spike, spit. See ***Ayah-Śulika***. (5.2.76)

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Śulya : referring to spike or spit roasting. (4.2.17)

Śṛgālagarta : Sealkot (modern) city.

Śṛṅkhala : chain, fetter. (5.2.79). *Sṛṇī* in *ṚV* is sickle.

Śṛ : to crush, injure, break. (3.2.173., 7.4.12)

Śoṇa : red, crimson. (4.1.43)

Śauṇḍika : distiller. (4.3. 106)

Śrī : light, lustre, radiance, beauty. (7.1.56)

Saṁyoga : intimate connection. (5.1.38)

Saṁsargin : mixed together, comingled. (3.2.142)

Saṁsṛja : to join, unite, mingle, mix. (3.2.142)

Saṁskṛta : perfected, made ready. (4.2.16)

Sakta : clinging, adhering. (7.2.18)

Saṁkāśa : (similar) look, appearance. (4.2.80)

Sattva : reality, substance, essence. (1.4.57, 2.3.33) Later this word was used to mean the metal (essence) in the ore mineral. The word comes from *Sat* and is equivalent to *Satya*.

Saṁtāpa : great burning heat, glow, fire. (5.1.101)

Saṁdāva : incendiary. (3.3.23) Burning bright.

Samid-Dṛṣada : fuel stone or firewood. (5.4.106) Coal? lignite?

Samutta : well moistened, thoroughly wet.

Samudra : ocean.

Samparkin : mixed, blended. (3.2.142)

Sampad : wealth, fortune.

Sampṛca : to mix together, commingle. (3.2.142) From this *saṁparka*.

Sambandha : binding or joining together.

Sāra : core, pith, solid interior of anything, firmness, strength. (3.3.17) says '*sṛ sthire ghañ*' —*ghañ* affix comes after the verb *sṛ* (to move) when the agent is permanently fixed (*Sthira*) i.e. *Sṛ* + *Ghañ* = *Sāra*

SṚ means to move, run, flow, glide *Sarasvatī* that which flows, a river.

Sālva : the land between Alwar and Bikaner. (4.2.76)

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Sikatā : sand, gravel.

Sikatāvat or ***Saikata*** : sandy place. (5.2.104-105)

Sīra : a plough. (4.3.124)

Su : to press out, extract, distil. (3.2.103., 7.2.72)

Sṛ : to move.

Saindhava : marine, aquatic, oceanic, relating to the sea (*Sindhu*).

Snu : to drip, distil, trickle, emit.

Sneha : fat, oil.

Snehana : lubrication, smearing with oil or fat. (3.4.38)

Sneha-Vipātana : melting of a fatty substance. (7.3.39)

Sru : to flow, stream, gush out. (7.2.13) *Srāva, Prasravaṇa* (geyser) etc.

Sruva : from which a liquid gushes out, a ladle. (6.3.115) Liquid metal pouring — ladle for casting?

Hiraṇya : gold. (5.2.65, 6.2.55) *Hiraṇmaya* — golden.

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Appendix D

Some Typical Technical Words in *Kauṭilīya Arthaśāstra*

Akṣaśālā : workshop for the manufacture of gold and silver articles (2.13.1 and 30)

Agniṣṭha : an oven (2.14.24 and 53; 3.8.11)

Adhikaraṇī : iron vessel (2.14.53), an anvil (4.4.20)

Añjana : antimony compound/sulphide (2.11.35; 2.12.6 and 24; 2.22.6)

Abhrapatala : a covering of mica (13.2.25)

Aṣṭaka : lac (2.14.27 and 39)

Ākarika : mine-worker, mine (2.12.20)

Ācitakapatra : gold leaf for plating (2.14.25)

Ājīva : hardening alloy used in coining (2.12.24)

Ābandhya : ornaments, jewellery (3.2.14-15; 4.12.27-28)

Āyaskāntā : magnetic, containing a magnet (2.14.19)

Ārakūṭa : brass (2.12.23, 2.17.14; 4.1.35)

Āveśana : a factory, a workshop (2.13.1, 2.36.14)

Āveśanin : a workman (2.14.1 and 7)

Indranīla : sapphire (2.11.31)

Utpalavarṇa : gem, coloured like blue lotus (2.11.30)

Ūṣman : steam, vapour, heat (1.21.7, 2.18.3)

Aiṣṭaka : brick-built (2.3.7, 2.5.3)

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Kaṁsa : bronze (2.12.33; 2.17.14; 4.1.35)

Kaṭamāna : fastening of gold (etc.) for a gem at the sides (2.13.41)

Katuśarkarā : soft stone or pebble (2.14.37)

Karatukamukha : 'crane's neck', a kind of goldsmith's tool (2.14.23)

Karṇakīlāyasa : copper wire in the pillars at the corners or iron pegs at the corners (3.8.3).

Karmānta : a workshop or a factory (2.12.18, 23 and 27, 2.17.17, 2.19.1, 2.23.10).

Kaladhautaka : ornamental silver (2.14.8)

Kalanī : pulp (2.25.26)

Kalpanā : chopper or cutter (2.3.34)

Kākaṇi : copper coin one-sixty-fourth of a *paṇa* (2.12.24; 2.13.15-16)

Kāca : glass, crystal (3.17.8). In 2.14.53, *Kāca* implies pilferage.

Kācaka : fixing mica or glass in an article of gold. (2.14.40)

Kācakarmana : setting in gold or silver. (2.13.41 and 43)

Kācamaṇi : a glass bead (2.11.36)

Kācārpaṇa : seeting a gem in gold or silver (2.12.38)

Kāñcana : gold or silver base for setting (2.13.33 and 41)

Kāñcanakāru : an artisan working in setting gems etc. (2.13.33)

Kārukarma : artisan's work (2.14.17) see text for details, chapter 5

Kārmantika : the Director of Factories (1.12.6, 2.4.11, 5.3.7)

Kārmarika : manufactured by a smith (2.3.35)

Kārmika : works manager (2.1.38, 2.7.22-23, 2.28.27)

Kālāyasa : black metal or iron (2.13.55; 2.17.14)

Kāsīsa : iron sulphate (2.13.19) *puṣpakāsīsa*

Kitta : dross (2.12.1); *pūtikitta* (2.14.23)

Kutta : to pound (2.13.9)

Kuttakayantra : pounding machine (2.15.62)

Kuttanaśāla : a shed for pounding work (3.8.28)

Kūpya : forest produce (1.16.29, 2.17.1)

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Kuruvinda : corundum (2.14.48)

Kṣāra : sugar-cane juice, (2.15.14 and 64, 2.29.43, 2.30.18, 2.31.13) also alkali (2.12.9 and 27; 2.15.15)

Kṣudraka : minor work in gold (bead-making etc.) (2.13.37 and 40)

Kṣurakalpa : razor type weapons (2.18.14) see text chapter 5

Kṣepaṇa : setting or binding in gold or silver (2.12.37-38)

Khaḍga : sword (2.18.12) varieties see chapter 5

Gāndhāra : red lead (2.14.35)

Gomedaka : gem of cow-flesh colour (2.11.30; 2.12.6)

Candrakānta : see ***Nandaka***

Cuncuvālukā : fine sand (2.12.5)

Jatu : lac (2.14.35)

Jātarūpa : gold (2.13.3)

Jīmūtaprabha : gem with the lustre of dark cloud (cloudstone?) (2.11.31)

Ṭaṅka : chisel (4.4.20)

Tapanīya : gold specially prepared for making ornaments using heat (2.13.61)

Tapanīyakāru : a maker of ornamental gold (2.13.33)

Tapta : ornamental gold (2.14.8)

Tāmra : copper (2.12.23-24, 2.13.52 and 58, 2.17.14, 4.1.35)

Tāra : silver for ornaments (2.13.49, 2.14.30)

Tāla : bell-metal (2.12.23)

Tīkṣṇa : cast or carburised iron (2.12.15 and 24; 2.13.48 and 58)

Tīkṣṇa Dhātu : iron ore which produce iron (2.12.15) whitish-red (*sinduvāra* flower like) stone

Tuttha : a crucible for heating and purification of silver (2.13.49)

Trapu : tin (2.12.14, 23 and 24; 2.17.14, 4.1.39)

Triputaka : two parts of silver and one part of copper (2.14.20-21)

Tvaṣṭṛ : a gold plater (2.13.33)

Tvaṣṭṛkarmaṇa : gold plating (2.13.44)

Danta : tooth of an elephant or ivory (3.17.8)

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Dhātu : metallic ore (not metal yet) (2.12.7 and 12-18, 2.22.6)

Nandaka : a gem, white inside and blue outside, resembles ***Candrakānta*** (2.11.31)

Nālī : a tube, a blowpipe (2.14.23, 13.2.21)

Nālikā : a measure of time approximately 24 minutes standardised by the time required for the flow of a certain amount of water through a standard hole (1.7.8, 1.19.6, 2.20.35)

Nikaṣya : touchstone, actually streakplate for testing streak of gold and silver (2.13.17-27)

Paṇa : a silver coin (*Kārṣāpaṇa*) (2.12.24; 2.13.15-16)

Paṇayātrā : circulation of coin/currency (2.12.25, 4.1.44-45)

Padmarāga : ruby (2.11.29)

Paribhāṇḍa : the encircling metal (in the setting of gems etc.) (2.13.43, 2.14.37)

Pākamukta : product of crystallisation (2.12.28) (salt)

Pāñsudhāvaka : the dust-washer (in a mine or goldsmith's shop), (2.13.33; 4.1.49)

Pinka : embedding of metals, gems and chemicals (2.14.34-42)

Pūtikitta : dross or slag from furnace (2.14.23)

Pudgala : an article made of gold or silver (2.14.7 and 43)

Puṣyarāga : a gem, yellow like turmeric (2.11.30)

Pṛṣata : making of beads (of gold etc.), a bead (2.13.40, 43 and 60; 2.14.45)

Pṛṣatakāru : a bead-maker (2.13.33)

Petaka : enclosing of metals (2.14.26-33)

Peṣaka : a grinder (1.21.10)

Pautava : standardisation (from *pū* to refine) (2.19.1)

Pratāpana : heating (4.8.22)

Pravāla : coral (2.6.4; 2.11.42; 2.12.27)

Prātivedhanika : stamping of weights and measures (2.19.40), stamping fee (2.19.42)

Prāstara : consisting of rocks (2.3.1)

Phalāmla : sour fruit juice (acidic), (2.15.18, 2.25.39)

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Bimba : die for making coins (4.4.20)

Bīja : an alloy (2.12.24)

Bhastrā : skin bag, bellow (4.4.20)

Bhānda : article, container

Maṇirāga : the imparting of colour to gems (1.18.8, 2.12.1)

Maṇḍala : a metal ball (2.19.13)

Manaḥśilā : realgar, red arsenic sulphide (2.12.2, 2.14.48, 2.22.6, 14.2.17)

Mārjārakṣaka : cat's eye, a variation of beryl (2.11.39)

Māṣaka : copper coin, 1/16 of a *paṇa* (2.12.24, 2.13.15-16, 2.19.2-7)

Muktā : pearl (2.6.4)

Mukhalavaṇa : rock salt, salt from the Indus land (2.29.43)

Mudrā : stamp, seal (later coin) (1.20.23, 2.21.2 and 26, 5.3.41, 11.1.25)

Muṣṭika : a hand-vice (4.4.20)

Mūṣā : a crucible, (2.12.1, 4.4.20)

Mūkamūṣā : dummy crucible (2.14.23)

Yantra : a machine (2.15.62, 2.18.1, 10.6.48); a mechanism (1.20.2, 2.3.34, 2.5.2)

Yāntrika : a mechanic (10.3.44)

Yavakṣāra : caustic ash of barley (2.12.9; 2.15.15)

Yogāñjana : a poisonous collyrium which blinds (4.10.13)

Rasa : a liquid ore (2.12.2) ore from streams (?)

Rasapāka : the smelting of liquid ores (2.12.1-3)

Rasaviddha : smelted from liquid ores **or** obtained from streams (?) qualifying gold. Another kind of gold stated to be from the mines (2.13.3 and 6)

Rūpa : a coin (2.12.24; 5.2.61)

Rūpadarśaka : an examiner of coins (2.5.10, 2.9.28, 2.12.25, 4.1.44)

Rūpika : coining fee, manufacturing charges (2.12.26, 30 and 35; 2.6.10)

Rūpya : silver (2.12.5. and 6; 2.14.20)

Rocanī : the grinding mill (3.8.11)

Rocanīdṛṣad : the mill stones (2.15.62; 2.18.15)

Lakṣaṇādhyakṣaḥ : mint-master (2.12.24)

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Lavaṇādhyakṣah : master of salt works (2.12.28)

Lohādhyakṣaḥ : the director of metal-work (2.12.23)

Vajra : diamond (2.6.4, 2.11.37, 2.12.27)

Varṇa : colour or quality (2.14.5, 3.12.53, 4.1.30)

Varṇikā : the standard gold (2.13.17)

Vāsaya : to gild (2.13.46)

Vāsitaka : gilding (2.14.17)

Vāstuka : the base or frame of a gold article (2.13.43, 2.14.35, 39 and 46)

Viḍa/biḍa : salt containing chlorides of sodium and calcium, also sulphate and some red iron oxide (from sea-water) (2.15.15)

Vimalaka : white-red gem from Vimala (Girnar) mountains. Carnelian? Pyrite? (2.11.35, 2.12.6)

Viṣṭi : sappers, miners and labourers (9.2.9, 10.1.9 and 17, 10.4.17)

Vīja : additive alloying element to harden (2.12.24)

Vṛtta : steel or carburised iron (2.12.23, 2.17.14, 3.17.8, 4.1.35)

Vedhana : which transmutes through smelting (2.12.3 and 5)

Vellaka : an alloy of silver and iron in equal proportions (2.14.22)

Vaikṛntaka : a kind of metal (2.12.16 and 23; 2.17.14, 4.1.35). Some special kind of alloy of iron? Later *vaikrānta* meant a gem like diamond.

Vaidūrya : beryl (2.11.30)

Śaṅkha : conch-shell (2.6.4, 2.12.27, 7.12.24)

Śilājatu : bitumen or 'lac of the rock' (2.12.4)

Śukti : oyster, nacre (2.11.35)

Śulka : duty, toll (2.21.2)

Śulkaśālā : the customs house (2.21.1)

Śulva : two meanings: (1) copper (2.13.16 and 44; 2.14.20-22 and 30-31); (2) underground vein of metal ore (2.12.1) or water (2.24.1)

Śvetatāra : white silver (2.13.50, 51 and 54)

Sattva : the metallic content (or essence) (2.12.7)

Saṁyūha : to coat, to plate (2.13.44, 2.14.48)

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Saṁyūhya : the work of gold-plating (2.14.17, 26 and 50)

Saṁkara : impurity (3.14.38)

Saṁdhātya : fixing base metal in an article of gold or silver (2.14.17, 26 and 30)

Saṁdaṁśa : a pair of tongs (2.14.23)

Sasyaka : blue gem, copper sulphate (2.11.35, 2.12.6)

Sāra : an article of high value (2.5.8, 2.7.2, 2.11.1) strength (1.16.9, 8.1.61)

Sīsā : lead (2.12.6, 13 and 24; 2.13.6 and 47; 2.17.14, 4.1.39)

Suvarcikālavaṇa : borax (2.14.23)

Suvarṇa : gold of fixed weight 16 *māṣakas* (2.19.3, 2.13.15, 48; 4.1.28)

Suvarṇa Pāka : the smelting of gold (1.18.8)

Suvarṇādhyakṣa : the superintendent of gold-works (2.13.1)

Sūryakānta : sunstone gem (2.11.32)

Saindhavikā : earth or sand from the river Indus (2.13.47 and 49)

Saugandhikā : red gem spinel (or ruby?) (2.11.29)

Sauvarcala : borax (2.15.15)

Sauvarṇika : the state goldsmith (2.13.2; 2.14.1 and 11)

Sneha : fat (2.15.64)

Sphaṭika : quartz, crystal (2.11.32)

Sravanmadhya : bluish gem 'having rays shooting like flowing water' (2.11.31) Asteriated or star sapphire.

Haritāla : yellow orpiment, arsenic sulphide (2.14.48, 2.22.6, 14.2.17)

Hiṅguluka : vermilion, mercuric sulphide (2.13.19 and 46, 2.14.34 and 48, 2.22.6)

Hiraṇya : money, cash (1.13.6, 1.19.12)

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Appendix E

Some Technical Words in the Post-Christian Era Indian Literature Related to Minerals and Metals

Akik* : agate

Adrija : bitumen

Abhraka : mica

Amla : acid

Arka : sunstone

Aśmasāra : metallic extract, pig iron (?)

Ājīva : alloying element to harden

Ārakūṭa : brass

Indragopa : golden beryl or zircon (?)

Indranīla : sapphire

Utpala : greenish-blue aquamarine

Audbhida : plant ash alkali

Kajjali : cinnabar

Kankuṣṭha : tin ore (?)

Kankuṣṭam : purgative soil with Mg/Na sulphate

Kaṅsa : bronze, bell-metal

Kaṅsa-Mākṣika : coarse grained arseno-pyrite

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Karuṇḍaka : crimson-yellow ruby

Karketana : chrysoberyl

Karpūrarasa : calomel or mercuric chloride

Karmānta : factory

Kākatuṇḍi : leaded-brass turning black with acid

Kāntaloha : iron from magnetite

Kāṁkṣi : alum

Kāṁsya : bronze/bell-metal

Kāṁsya Vimala : arseno-pyrite or löllingite

Kāravellaka : non-laminated zinc ore

Kāśīsa : green vitriol or ferrous sulphate

Kiṭṭa : dross

Kuṭila : tin

Kuruvinda : corundum

Kṛśan : conch-pearl

Kṣāra : alkali

Khaṭikā / Khaṭī : steatite chalk

Khani : mine

Khanija : mineral

Kharpara : zinc ore, calamine, sphalerite (?)

Gandhaka : sulphur

Garuḍodgāra : emerald

Galu : gem

Gāndhāra : red lead

Gārutmata : emerald

Gairika : red ochre, hydrated iron oxide

Gomeda : zircon, hyacinth, jacinth

Ghoṣa : bell-metal; 20 p.c. tin in copper, makes sound

Candrakānta : special feldspar, cloudstone (?)

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Capala : quick-melting tin or bismuth ore

Cīnāmāti : China-clay or Kaolin

Cuṇī* : ruby, from *cūrṇikā* or small ruby

Cunā Pāthar* : limestone, produces *cūṇa* or lime

Culikā Lavaṇa : sal ammoniac

Jabarjad* : Olivine, peridot

Jawharmuhra* : jade

Jāmīrā* : purple amethyst; quartz with Mn

Jārana : amalgamation

Tankana : borax

Tāmḍi, ***Tāmrya***, ***Tāmri*** : garnet, carbuncle

Tāmra : copper

Tāra : silver

Tārāmaṇi : star sapphire

Tārkṣya : emery or corundum with iron

Tāla : orpiment, bell-metal

Tālaka : orpiment

Tīkṣṇa : steel, carburised iron

Tīkṣṇa Dhātu : iron ore

Tutthaka, ***Tnute**** : blue vitriol, $CuSO_4$

Tuvāri : alum

Trapu : tin

Darada : cinnabar

Dastā* : zinc

Durdura : flaky laminated zinc ore

Drāvaṇavarga : flux

Dhātu : metal and metal-bearing ore

Navasāra : potassium chloride/carbonate fertiliser

Nāga : lead

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Nikaṣya : streak-plate

Nirvāpa : quenching

Nīla / Nīlakānta : sapphire

Nīlagandhi : red ruby with a blue tint

Nīlāñjana : stibnite or carrollite

Padmarāga : ruby

Pānnā : emerald

Pārada : mercury

Pāribhadra : aquamarine

Pālaṅka : onyx

Pitala / Pītatāla : brass

Pīlu* : jade

Puttika : olivine, peridot

Pulaka : garnet?

Puṣparāga : topaz

Puṣyarāga : topaz

Pūtiloha : low m.p. metals

Peroja*/Pīroja* : turquoise

Pokhrāj* : topaz

Pogara : cementite streaks in carburised iron

Pravāla : coral

Phatki*/Phullikā : alum

Bālasūryaka : spinel balas-ruby

Billaur* : quartz (or velur/beryl?)

Bīja : alloying element to harden

Bhastrā : bellow

Bhidura : diamond

Bhīṣma : quartz or chalcedony ?

Makaradhavaja : mercuric sulphide

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Maṇi : gem

Maṇirāga : imparting colour to gem

Maṇḍūra : rust of iron

Manaḥśilā : realgar

Marakata : emerald

Marmara : marble

Masāra : emerald (from Misar / Egypt?)

Mākṣika : pyrite

Mākṣika Kaṅsa : arsenopyrite

Mākṣika Tāra : pyrite

Mākṣika Swarṇa : chalcopyrite

Mākṣika Hema : chalcopyrite

Māṇikya : gem, ruby

Māraṇa : incineration, oxidation of metal

Mārjārākṣa : cat's eye, chrysoberyl

Miśraloha : alloy

Muktā : pearl

Muṇḍaloha : wrought iron

Mūṣā : crucible

Mṛddārāśṛṅga : anglesite or litharge, yellow PbO

Yaśada : zinc

Yaśadāyaka : zinc

Yaśam : jade

Yukta : alloy

Rajata : silver

Ranga, Rung : tin

Rasa : mercury, liquid or melt

Rasaka : zinc metal or ore, calamine

Rasakarpūra : mercuric chloride

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Rasapāka : smelting of ores to liquid state

Rasasindūra : mercuric sulphide

Rasāñjana : stibnite or mercuric sulphide

Rājāvarta, Lajward* : lapis lazuli

Rāng* : tin

Ritikā : malleable alpha-brass

Rīti : brass, calx of brass

Rukham* : alabaster

Rudhirākṣa : carnelian

Reh* : soil containing sodium sulphate and bicarbonate

Raupya : silver

Raupyamal : calx of silver

Lavaṇa : salt

Lasuniyā* : garlic-like chrysoberyl, cat's eye

Loha : metal 'which is extracted'

Lohavedha : metallic transformation

Lohitākṣa : carnelian

Lauha : iron

Lauha Kānta : magnetic iron

Lauha Tīkṣṇa : carburised iron, steel

Lauha Muṇḍa : wrought iron

Vajra : diamond

Vaṅga : tin

Vaṁśamuktā also ***Vaṁśa-Locana, Tvakṣāra*** : bamboo-pearl

Varanāga : 'lead-like antimony', alloy of Sb/Fe

Varaloha : Cu/Fe alloy

Varāṭikā : marine nodule

Vartaloha : alloy of five metals : Cu/Fe/Pb/ brass and bell-metal. Also known as *Pañcaloha*

Vahṇimṛttikā : fire-clay

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Viḍalavaṇa : reacting black salt, 'kills' gold

Viduraka : chrysoberyl, cat's eye

Vidruma : coral

Vimala, Vimalaka : pyrite

Vimala Kāṁsya : arsenopyrite

Vimala Tāra : pyrite

Vimala Hema : chalcopyrite

Veḷuriya* : beryl

Vellaka : silver-iron alloy

Vaikṛntaka : magnetic iron or iron from magnetite

Vaikṛntakadhātu : magnetite

Vaikrānta : tourmaline

Vaidūrya : beryl

Vaidūrya Nīla : aquamarine

Śaṅkha : conch-shell

Śastra : steel, weapon

Śastrapāna : quench-hardening of *śastra*

Śilā : rock, realgar

Śilājatu : bitumen

Śukti : oyster

Śulva : copper, underground vein of metallic ore

Śulva-Ari or ***Śulvāri*** : sulphur, 'killer' of copper

Śulvanāga : Cu/Pb alloy

Śeṣa : onyx

Śodhana : purification

Śorā/Sorā : saltpetre KNO_3

Satva/Sattva : metallic essence in an ore

Satvapātana : extraction of metal

Sarjikā Kṣāra/Sarjikā Mṛttikā : river-bed alkaline soil with $Na_2SO_4/NaHCO_3$

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Sasyaka : blue vitriol or $CuSO_4$

Sīsaja : red lead

Sīsā : lead

Surmā* : collyrium, stibnite

Sulemāni* : onyx

Suvarcikā : borax

Suvarṇa : gold

Sūryakānta : sunstone

Sonelā* : yellow quartz with iron oxide. False topaz.

Sohtā* : carrollite

Sohāgā : borax

Saugandhika : yellowish-red spinel ruby

Saubhāgya : borax

Saubhirāñjana : stibnite

Saubhrācala/Sauvarcala : alkaline sochal salt; borax or saltpetre (?)

Saurāṣṭraja : alum

Snapana : quenching

Sphaṭika : quartz

Sravanmadhya : asteriated or star sapphire

Srotāñjana : carrollite

Svarṇa : gold

Svarṇa Mākṣika : chalcopyrite

Harā Kāśīsa : green vitriol $FeSO_4$

Haritāla : orpiment (Also löllingite?)

Harinmaṇi : emerald

Hiṅgula : cinnabar

Hīraka/Hīrā : diamond

* indicates non-Sanskritic words.

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